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Vol. 249 MAY, 1950 No. 5

VISION KNOWS NO BOUNDARIES[1]

BY

WILLIAM L. BATT[2]

The subject I have chosen for tonight, "Vision Knows No Boundaries," finds itself in a happy atmosphere. Few men in the history of our country have been blessed with that extraordinary combination of homely virtues, shrewd vision, high intelligence and sturdy pioneer courage which characterized the man whose shrine this is. I never look into the fine face of Benjamin Franklin as one sees it in the Great Hall without a deep sense of humility. But there is, in his quizzical half smile, some benign encouragement seeming to say that if we think it useful to talk together for awhile about the life and work of one of his admiring—and admirable—descendants, then we shall have his blessing.

One cannot be unmindful of the honor of delivering the second of the lectures under the auspices of the Edward G. Budd Lecture Foundation. I am truly appreciative. The first of these was given by the distinguished Dr. G. L. Kelley of Oxford, England. It was natural and appropriate that he should lay a foundation for those who should follow him by outlining in some detail the life and work of Mr. Budd and the more noteworthy steps in the development and growth of those great American industrial institutions which proudly bear his name.

I shall not try to cover that ground again, interesting and significant as it is, but rather I'd like to exercise my poetic license and philosophize with you upon some of the larger consequences which flow from the sort of industrial enterprise typified by Mr. Budd's life.

My title tonight presupposes two themes which I shall try to develop —the one "*Vision*," and the other "*New Boundaries*." For it was because men like Mr. Budd had great vision that far-reaching social

[1] Presented under the Edward G. Budd Lecture Foundation of The Franklin Institute; given in the Lecture Hall at the Stated Meeting held February 17, 1950.

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and economic events flowed from the dreams which he reduced to successful practice. At their moment of conception they can hardly have appeared to him and his small group of associates as the far-reaching picture which they have now become, to say nothing of the ultimate shape they may acquire.

Rarely does any pioneer see clearly what his destination shall be or how he is to reach it. But one thing we can be sure of is the existence of an impelling urge that drives such men to make the effort, whatever it may cost in sacrifice and time. It is this unquenchable intent, this inflexible and unyielding purpose, this divine spark of motive power, this vision that sees something eminently worthwhile lying beyond the horizon of men of lesser imagination. I know vision of this kind characterized Edward Budd and a few other men of his time and it is fitting and rewarding for us to think about it, in the way it bears upon the lives of those who shall come after us.

Young people everywhere today are sure to question whether things aren't different and more difficult now, and to doubt that the same opportunity for success exists in these rapidly changing times. To them I would observe merely that this question has always been raised by one generation about another. The son wonders if his father really hadn't security of a better kind than now and many more chances of getting ahead. The father, on the other hand, sometimes despairs of finding in this modern generation any of the good old qualities of his boyhood.

Of course, things are different today from those in Mr. Budd's early business life. They are different but not necessarily more difficult: To be a wealthy man today is certainly more difficult. But success need not be measured only with a monetary yardstick and young men are this day, as they will be in every day to come, making careers for themselves which must be called successful, when they have these essential qualities of success. It may be—and often is—argued that modern taxing programs of government operate to lessen incentive and thus limit the likelihood of new pioneering in industrial enterprise. We hear the question asked that if one is not to be allowed to keep any large part of what he earns what is the use of unusual effort to make a financial success? A logical and serious question.

But if merely making money had to be the motivating force in the life of a successful man, we should not be hailing Edward Budd as we are. For, so far as I can gather, that was probably one of the last things he ever had in mind. I suppose that some bankers had many sleepless nights in those earlier days because they were apprehensive that he hadn't enough respect for making money. Faced with the challenge of a piece of research whose possibilities interested him, a little thing like the lack of money didn't cause him sleepless nights, or, if it did, he concealed that pretty well from his public. To do the job—

to find the solution—to get ahead—to make the new thing that research so eloquently promised—these were the irresistible urges that motivated Mr. Budd, just as they have all those other industrial pioneers in their determined search for new boundaries.

The deep conviction these men had in the rightness of their objectives—a conviction that took almost the form of a righteous crusade—made them, surprising as it may seem, unusually effective salesmen. It was a hardened and unimaginative purchaser who failed to find himself convinced of the desirability of something one of these men was urging; indeed, Mr. Budd would ordinarily succeed in making an oldtime railroad executive, who demurred at the revolutionary idea of a lightweight, streamlined passenger train, feel a certain sense of guilt and shame at his own lack of vision.

The significance of this to me is that, when a man believes wholeheartedly in some one thing and with singleness of purpose devotes himself to that thing, he can do almost the impossible in persuading others to help him get on with it.

On this point of singleness of purpose, it is worth noting, I think, that most of these great pioneers led unusually Spartan personal lives. If this had no other effect or significance, it emphasized their unwillingness to fritter away their energies in unnecessary or inefficient or wasteful use of time or money.

There was another difference in their day's work as compared with yours and mine. So far as I can judge, these men did few things outside their business. It disturbs me to see so much of my time spent on a whole host of extra-curricular time-consuming activities—you know what they are—which people look to us to do. We think it is justifiable in the interests of the general welfare, but it is appalling that so many of our hours are taken away from our major responsibility as executives. How much of the ability of these pioneers to do great things came from this more intense and singleminded devotion to their work is anyone's guess.

Now, lest I overlook this, it seems to me essential to point out to the generation of today that such men as Mr. Budd and Mr. Ford and their companies were certainly not unfamiliar with risk and insecurity. At one time or another they were in real financial danger and their ownership and management were seriously threatened. If any of you younger people think of them as always secure and safe, and contrast a feeling of uncertainty you may have about life of today, you had better think again. They were always taking risks; they were frequently criticized as unrealistic experimenters. I must not overlook one factor obviously in their favor in this respect and contributing to their independent or autocratic behavior. This was that they were ordinarily the principal owners of the enterprise, and they had no need to look behind constantly for the reactions of a group of stockholder interests.

I shall never forget a day and a night I spent in Mr. Edison's laboratory when I was a young engineer. Our little company was interested in finding ways and means to measure comparatively the noise made by ball bearings as they revolved. With today's science of electronics that is child's play, but at that time it was all new ground. One could listen and conclude that this part was noisier or quieter than that, but how to obtain a positive comparison and use it as a basis for future development, we did not know. Neither did anyone else. But it came to our notice that Mr. Edison and his associate, Mr. Hutchinson, were studying sound in their East Orange laboratory and a way was found of letting this young Philadelphia neophyte learn something about it. And the picture I got of Mr. Edison at work relates to the point I want to make.

First, this simple and unostentatious quality of success that is called work. Not a colorful or romantic qualification, but I know of very few men who have succeeded in any field without a lot of it. When Mr. Edison started a project he stayed with it—literally day and night—until he got some sort of an answer.

In that laboratory I was first struck with the fact that no one seemed to have any idea of going home at the end of the day. Some sandwiches and milk and coffee came in, but things went on. Two or three cot beds in the corner struck me as odd. "We take a little nap when we have to, but the work goes on until Mr. Edison is satisfied to quit, whenever that is," was the explanation. No timeclock, no movies, no dividend requirements, no bankers, and, I might add, no labor union or overtime restrictions, worried these determined pioneers as they followed their visions to the end. This is one of the elements of a successful career in their time which is just as necessary in ours.

I know there is a natural temptation to dislike to accept this conclusion as bed-rock and to think of one's day and week in terms of eight hours and forty. A good deal of loose talk about overwork and more leisure—what the machine has done to lessen man's burdens and so on—can hardly fail to have had some influence on the mind of a young man starting to build a career. But any employer will tell you that he is always looking for those few men in his organization—there never are many of them—who have initiative—who do independent thinking—who seem to have the interest of the business at heart and will work at it not because they are told to but because they have the inner urge in them to do a job and do it well.

I know nothing about Mr. Budd's characteristics as a young man, but I shouldn't be surprised if what I just said were not a pretty good description of his attitude as a young man. Few worthwhile things in life ever have or ever will come easily. There is no labor-saving device that can replace the mental work in a successful career. That was true of Mr. Budd, and of Mr. Ford and Mr. Firestone, of Mr.

Vauclain and John Wanamaker, and all their kind. It wasn't money they were after or personal advancement or more comfort. And for what the thought is worth, they didn't retire at 65, either.

Some of their qualities were not those we should advise a young man starting in business today to cultivate. All too frequently they were stubborn, willful, intolerant of differing opinions. The modern development of corporate organization, with divided responsibility, committee decisions, Junior Boards of Directors and Senior Boards—that was no part of their concept of management. They violated pretty nearly every rule that we consider basic today. That they got away with it, and dramatically, is difficult for us to understand. The amazing virility of such concerns, usually named after the founders, always excites one's admiration. They can have their bad times—they can do these things that seem inexcusable to us today—and yet not have too much trouble. Perhaps that is because, instinctively, most of us have such a deep-seated respect for the creator and builder, that we will readily forgive him acts we would condemn in anyone else. But I remind myself that there is always danger in drawing too many conclusions from the lives of successful men. We must not forget that the business graveyards of that day were also full of failures; and if it were possible to exhume them we might find that the successes we know of and admire were only exceptions that prove a rule.

Now here I am, looking so much at the past while much of this audience is far more concerned about today and tomorrow. Certainly they will revere the qualities of these pioneers and admire their accomplishments, but a young man entering business life today can fairly ask what his chances are of becoming a Ford or a Budd or at what level his sights ought to be pitched. Have times and people changed?

If he had laid out clearly in front of him a blueprint which detailed the ways in which these pioneers had worked and the standards they aimed toward in their own enterprises, would it be safe for him to adopt those for his own? Studying the history of the past can be a pleasant intellectual exercise, but if it fails to establish some bench marks by which a new traveler can chart his course with greater safety and assurance, it loses much of its value for any man. Does the social and economic structure of today demand more or different things from its business management than that of a generation or two ago? If it does, one may properly ask whether the qualities that made these giants of yesterday what they were, are applicable now? This is a sixty-four dollar question and I may be foolhardy in attempting to answer it. But, begging your sympathetic indulgence, I will try, for otherwise nothing I shall have said tonight has any helpful substance.

Yes, it seems a reasonable conclusion that times have changed and that the public attitude toward business has changed. No longer do you find business management indifferent to what the public thinks

about it, whether the public be looked at primarily as a customer group —as in the case of consumer goods—or as government or as labor. Increasingly it is being forced on us managers that we are no longer free to do merely as we think best, but that we must take sharply into account what other elements of our economy think about us.

A great concern like General Motors has over four hundred thousand stockholders (56 per cent of whom are women), and about the same number of employees. Significantly, both groups are potential customers, and in that role they are of major importance to the G. M. management. These people will not necessarily think as groups, however much they may at times act that way, and their feelings toward the company as stockholders or employees will certainly have a material bearing on their actions as purchasers of automobiles. And don't overlook another vital relationship this same huge group of people has to business: They are voters, and a large percentage of them are women whose emotional reaction may not always correspond to an impersonal balance-sheet analysis. They may not know too clearly what they can do as individual employees or even as stockholders, but they do know about their franchise as a voter.

Certainly all this must be a part of a great social change that reflects a new attitude of the public toward the management of business. Whether as stockholder or employee or as voter, he is apparently determined to regard the business structure not as an end in itself, but rather as a means toward an end. What more can I get out of it? That's what he is demanding, with ever-increasing emphasis. This is specially true of labor, or more accurately I think, organized labor leadership. So many of them seem to think that the corporate treasury is a bottomless barrel. This may be due, in part, to the tendency to remember the great personal fortunes of a few men of the past and to continue to associate them with the business of the present. It would be a useful exercise for all of us to look again at the earnings of most American companies as of today in terms of sales and capital invested.

Frequent inquiries of the average man in the street as to what he thinks are typical earnings today and what he considers reasonable, invariably disclose that his ideas of what are usual are far too high and that what is being earned actually falls well below his standard of reasonableness.

The annual statement of the American corporation eloquently bears out the widening concern of management for the good will of stockholders. It hasn't been long since the annual report disclosed as little information as possible. In an earlier day any suggestion that such a report should tell everything there was to be told, and illustrate it with photographs and even cartoons would have been regarded as downright silly if not actually dangerous. Stockholders now find regional meetings scheduled to suit their geographic convenience; special trains to carry

them to the meeting point when the law makes it remote, the whole embellished by the personal participation of top management and topped off with food. Before long, perhaps, even a cocktail party for those who have such preferences. Shades of the past!

If management has been careless in telling this story in the past—and it certainly has been—more and more effort is being made today, even if that has come about under public pressure. Most of us recognize it as a desirable change, for no company, no matter what its size, can hope to prosper if it is indifferent to how the public reacts to its policies and decisions. The Securities and Exchange Commission and its regulations were soundly denounced when they became law, and some modest changes might still be made today, but a proposal to wipe it off the books would not be seriously supported, even in business circles.

In what I have been saying there has been special emphasis on those aspects of managerial trusteeship that apply to the broad public interest in business conduct. Management has a responsibility to labor, too, although I must admit that at the moment this is all too frequently an unappreciated obligation. As to precisely what this moderating factor should be, and where and when it should be applied, I am certainly not clear; but I really believe that, at heart, the average employee feels more kindly toward and satisfied with the management that employes him, than his so-called "mass behavior" would lead one to conclude. This is really as it should be, for where can there be more similarity of real interest than between these two essential elements of the same business structure and on whose welfare both depend? Where friction does exist, a large share of the blame probably must be laid on management's shoulders for failing to find the means of holding the confidence of its working partners, although from unhappy personal experience I know how thankless a job this can be. But we are all learning and we should not be discouraged.

Husbands and wives and parents and children have found no sure-fire formula for happy family relations, either. The processes of collective bargaining—1950 model—certainly represent new boundaries that would have taxed individualists like Mr. Budd and Mr. Ford at their best—in fact, I'm not at all sure that their qualities (unless they were adjusted) would have enabled them to be nearly as successful in today's industrial life.

Another region to which they gave little attention is that having to do with government. Businessmen of a generation ago were inclined to treat that relationship either with indifference or disdain. When situations did arise, they had their own methods for dealing with them. You and I cannot afford to be so indifferent or arbitrary. The heavy hand of government touches us at every tender point of our corporate anatomy—through taxation, control over our distribution policies, regulation of many of our charges, of our labor relationships, of

our contacts with each other. These are only a few of the ways in which government has already stepped into the life of the businessman of today.

Let us consider for a moment this new device of the fact-finding board. The influence of such agencies in reconciling differences between labor and management can hardly be accurately appraised as yet, but the effect of this new and apparently fashionable approach may be far-reaching indeed. Certainly the first major application of this technique, in the steel industry controversy where the board recommended a pension plan at the sole cost of the employer, will have too far-reaching an effect to be properly evaluated now.

The idea of bringing in a small group of disinterested observers to decide what are the basic facts in a labor situation involving the overall welfare of the economy, is hard to attack in principle. But in practice, here's what happens: The selection of these men is obviously bound to have political connotations, and yet their findings are almost equivalent to those of a court of law because the public will be inclined to accept them at their face value. It is idle to say that they do not do away in large part with normal collective bargaining processes. They are likely to put men back to work and so relieve the pressure on the nation's economy, but they may do so at an unjustified cost in the long run.

A gratifying experience on the positive side has been our recent experiment in Philadelphia with the Commission appointed by the Mayor to deal with the threatened strike in the city's traction dispute. Although I conclude that the form of the seven-man panel, made up of management, labor and the public, all practical men, had a good deal to do with its success, this is beside the point. The essential thing is that a solution acceptable to labor, to management and to the public was found and a tie-up of the city's vital transportation artery was avoided. I shall not stress this further than to point to it as evidence, if that were needed, of the tendency of government, generally supported by vocal public sentiment, to move in to the area of business and labor management whenever it thinks the greater good will result.

But I should be remiss in trying to assess the significance of fact-finding boards if I failed to suggest that a more alert management might well have made some of them unnecessary. And this is particularly to my point this evening. For management should have seen that existing pensions for hourly workers were entirely inadequate and that any discrimination in principles between salaried and hourly workers would be likely to break down in time. Wiser management groups would have got strongly behind a program for larger federal old-age benefits where the sounder principle of sharing the cost was already nationally accepted. If this had come about, our pension structure might be on a far sounder basis today. It is because the costs of what

we are now almost taking for granted are so very high that I emphasize this lack of earlier vision.

For those who may not accept my reasoning that there is an accelerating movement of government control into every phase of our daily life, I would suggest that they look at these conditions in other generally similar parts of the world. England, Sweden, France and to a lesser and more recent extent, Australia, have had more or less industrialized economies like our own. There the limitations on the freedom of venture capital or private enterprise are far more severe. The reason, as I see it, is that in these countries the public has been compelled to turn to government for the realization of more of its wants and hopes. This has come about, no doubt, because of a generally lower standard of living, of high prices—the feeling that the worker cannot afford to purchase the things he helps to make. Altogether there is an atmosphere in which the customer is helpless in the face of selling controls of one kind or another that give him little freedom of choice. And this has been intensified by a maze of government controls which definitely tend to destroy initiative and incentive. And mind you, most of these restrictive practices, both private and public, have been put on in quest of some sort of security for someone or something.

We might as well be reconciled to the inevitable. There is likely to be more government rather than less. But being reconciled certainly does not mean indifference. You and I will be well advised to make the most determined effort to understand the forces that operate in government; to try to earn its good-will by intelligent cooperation, its confidence by straight-forward dealing. For men in government are only you and me and our neighbors. We put them there. We need to help them and if they won't be helped, to replace them with men who will. I shall leave this area of managerial trusteeship with the passing observation that some of our difficulties today may well arise from the indifference to what the public wanted on the part of those industrial leaders who came before us.

Whenever I think about these present-day controversial issues—capitalism, socialism, statism, the fair deal, and so on—the lives of such men as Budd and Ford and Edison shine through that foggy area like beacons. Not that I think their political and economic views are fully applicable today, because I don't. Nor would I have it appear that I am comparing these great men of the "good old days" and their heroic accomplishments with the men of our day and their work. I have no nostalgic yearnings to bring those days back, if I could. But one thing they did mark and that was the beginning of an era of magnificent production of material things. These things have done much to make life more comfortable and to prolong it.

More things for more people; unswerving confidence in production; good business and high incomes; respect for the business system and

not cheap condemnation of it—these are the hallmarks of our success. It has become too fashionable in these recent years to deride these objectives as old-fashioned and out of date. It has become too easy to substitute government help for self-keep. It has become too easy to mortgage the future to pay for the present.

> To find that better balance between the ability to produce the things for a better material way of life and to make more of them available to the people who produce them; to enlarge the satisfactions people must have if they are to work more efficiently and so lower costs; to provide more security for the worker and, at the same time, more incentive for new risk capital; these are not merely academic exercises modern management may dally with at leisure. They are thrown at it every day with violence. The whole world is seething with this experiment and that. All the "isms" find their fertile soil in this determined movement of masses of men in all the civilized communities of the world to achieve a larger share of the earth's economic resources.

This movement of men to better the lot of themselves and their children can be, in this day of warring ideologies, a movement for good or for evil. That it can be a force for good is the underlying principle of the Marshall Plan and the more recent proposal to help the underdeveloped areas of the earth to help themselves. In both plans, and more particularly in the program for the rehabilitation of Western Europe, are powerful ideas that most certainly will shape the course of the future.

Vision which knows no boundaries gave birth to the Marshall Plan—the kind of vision we shall need so desperately in our international relationships in the trying days ahead. Here are new ideas which offer hope to a world still struggling to get back on its feet. Here is a new experiment—a conscious and planned effort to restore other nations to economic prosperity. Its success will not turn so much on a balance sheet of facts and figures as on the ideas it releases from the minds of those who are being helped. For in these unpredictable ideas that move men lies our destiny.

This then, is a battle for the minds of men. It hardly seems to me that merely producing more automobiles and more radios and more electric refrigerators, as comfortable as those things are and as directly related to jobs as we know them to be, will provide any satisfying answer.

There is, of course, no single solution. One substantial hope lies in the larger acceptance by business management of the obligation of trusteeship. There is today, more than ever, an opportunity for enlightened management to win, by wise planning and intelligent leadership, the confidence and respect of every segment of our economy.

For the younger man, in whose mind vision is most productive, there lies even greater opportunity.

"Your old men shall dream dreams,
"Your young men shall see visions."

It is to them that I have tried to talk tonight. In their hands, and in the hands of those soon to follow, is entrusted the future of this great land of ours and, indeed, of the world itself. As Mr. Budd once observed, "It is a great adventure to live today—and in America."

Their job will by no means be easy. It is all the more difficult because their trusteeship comes at a time when we are seeing a social revolution of a magnitude unimaginable a quarter of a century ago. Into the space of a few years have been telescoped changes that ordinarily would have taken many more years to accomplish. Unfortunately, these changes have been accompanied by disturbances, some of them serious, and it might properly be asked, how much controversy can our economy withstand?

Like the delicate mechanism of a precision watch, our productive society is so highly developed and so finely balanced that any serious interference with the normal functioning of one part is certain to affect the smooth running of other components. Yet we know we can never be without these disturbing influences for we cannot be rid of conflict. To have differences is normal. The important point is to keep them from reaching the point where they do irreparable harm.

Never in our history has there been a greater, more urgent need for statesmanship—in management, in labor, in government—than now and in the future. We have had too much of selfishness and greed and too little of wisdom and understanding. The things that we do, and which we will be asked to do in advancing the welfare of our people, will call for social intelligence and social justice of a high order. Above all, they will call for vision—the kind of vision that has made this country the hope of freedom-loving peoples everywhere.

"Where there is no vision, the people perish."

New Industrial Television System.—A new and highly effective television system that extends human sight far beyond normal limits for benefits to science, industry and education was disclosed and demonstrated in New York recently by Dr. Paul K. Weimer and other research scientists of RCA Laboratories.

The new system, which produces excellent black-and-white pictures at normal light levels, can be adapted to produce pictures in natural colors, according to Dr. V. K. Zworykin, Vice President and Technical Consultant of RCA Laboratories, who directed development of the system. He said that, whereas surveys have indicated that black-and-white pictures will meet the requirements in most industrial uses, RCA engineers are working on color equipment to fulfill needs that may arise.

Described as the smallest and simplest system ever devised for non-broadcast, industrial television operations, the new RCA system is based on a remarkably small and sensitive pickup tube known as the Vidicon. The system consists solely of two units—a television camera approximating the size of a personal 16 millimeter movie camera and a master control monitor that can be carried as easily as a suitcase.

Details of this industrial television system were reported in technical papers presented by Dr. Weimer and Richard C. Webb, of RCA Laboratories, at the 1950 Convention of the Institute of Radio Engineers. An informal demonstration of the equipment showed its flexibility and effectiveness of performance.

In describing the Vidicon tube, Dr. Weimer said that, despite its reduction in size to less than a tenth of that of the image orthicon, the new tube is able to transmit pictures at normal lighting levels and to attain a resolution of more than 500 lines. The tube is only 1 in. in diameter and 6 in. long.

"The simplicity of the construction and operation of the Vidicon can hardly be overemphasized," he declared. "It contains only an electron gun and a target, as contrasted with gun, two-sided target, image section and electron multipliers of the image orthicon tube. The Vidicon's related equipment is proportionally less complex."

Dr. Weimer said that a number of materials have been found to be satisfactory for the photoconductive target and that, by proper selection and processing of the materials, it is possible to make a target sensitive to the entire visible range of the spectrum.

Whereas the Vidicon was designed specifically for industrial television, he added, intensive research is being carried on at RCA Laboratories in the development of tubes of this type for use in RCA's new all-electronic, high-definition color television system. Moreover, he said it is expected that further development of the Vidicon will improve its quality sufficiently to make it a valuable device in commercial black-and-white telecasting.

Portions of the rocket which reached a 250-mile altitude over White Sands, N. M., last winter, have been found accidentally by the Army Ordnance Department, long after search for the unreported two-stage missile had been given up. The rocket consisted of a German V-2 with a smaller U. S. Wac Corporal rocket attached to the nose. Found with it was an electrical connection used in loosing the Wac Corporal, which engineers believe would still work.

SERVO THEORY APPLIED TO FREQUENCY STABILIZATION WITH SPECTRAL LINES[1]

BY

W. D. HERSHBERGER[2] AND L. E. NORTON[3]

In an earlier paper (1)[4] the writers described work in which stabilization of frequency was accomplished using the absorption lines of ammonia which occur in the 24,000 megacycle frequency region. The advantages which arise from the use of such lines, namely, high inherent Q of 100,000 or more, and high long term stability which results from the use of a natural and universal standard of frequency were discussed in some detail. A long term stability of better than 1 part in 10^6 was reported in the paper, but no upper limit could then be placed on this stability due to inadequacy of monitoring equipment. Applications to television relay work, to radar beacons, and to frequency multiplier chains to control a clock were also outlined. Obviously much work, developmental in character, based on the servo-search principle employed in the work reported remains to be done. The purpose of the present paper is to discuss the applicable servo theory, to describe some of the circuits in fuller detail, and to report the present status of the work.

In essence, in this method a cyclic comparison is made between two frequencies: one the fixed frequency of a gas-absorption line, and the second a frequency to be stabilized or related to that to be stabilized in the simplest case by the relationship

$$f = \frac{f_{gas} \pm f_i}{n}, \tag{1}$$

where n is a whole number and is the order of a harmonic, while f_i is an off-set frequency. Conventional methods of frequency multiplication and addition may be used to make accessible for stabilization any one of a wide range of frequencies, by choice of n and f_i, both of which are at the disposal of the circuit designer. These techniques are of course old, hence need not be described. The comparison is made by means of a sweeping technique. A pulse is generated each time the frequency of a swept oscillator passes through the frequency of the gas line and also

[1] Much of the material in the present paper was presented before a conference sponsored jointly by the AIEE, the Institute of Radio Engineers, and the National Bureau of Standards, in Washington, D. C. on January 10, 1949. An abstract was printed in *Electrical Engineering*, Vol. 68, pp. 251–252, March, 1949.

[2] Professor of Engineering, University of California, Los Angeles, Calif.

[3] RCA Laboratories, Princeton, N. J.

[4] The boldface numbers in parentheses refer to the references appended to this paper.

each time one passes through a frequency defined by Eq. 1. The two wave forms carrying this frequency information are fed to a detector whose output is zero when the two sets of pulses or wave forms are in time coincidence but the sign of the output of the detector is such as to correct for frequency drift of the oscillator to be stabilized when the servo loop is closed by a connection to an element which controls frequency, as for example the reflector of a klystron tube or the grid of a reactance tube.

The discriminator itself may take a variety of forms. Figure 1

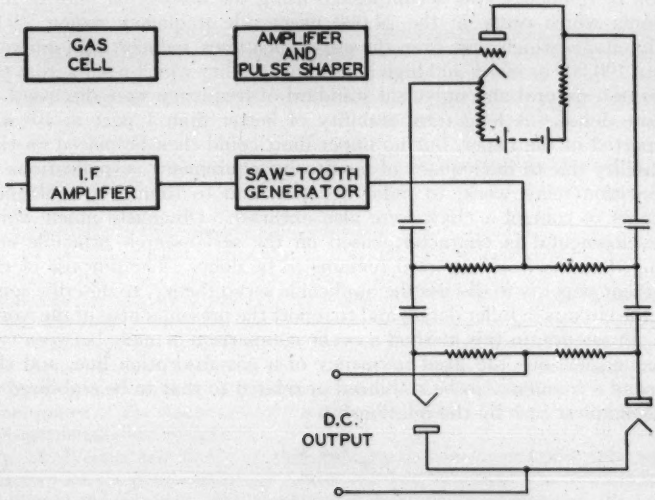

FIG. 1. Frequency-discriminator using pulse coincidence.

shows a form in which one starts with two sets of similiar pulses. The pulses from the gas cell after amplification are differentiated, clipped, and shaped and both positive and negative pulses coincident in time appear in the output of a final stage. These pulses convey or carry precise frequency information. Pulses from the i.f. amplifier channel of reference (1) are converted to a saw tooth wave. This saw tooth wave and the positive and negative pulses are fed to a pair of diodes whose output is the desired control voltage. A discriminator sensitivity of 200 volts per megacycle is readily realized with the above arrangement. Pulse coincidence detectors are also described in a number of U. S. Patents (2). The operating point of the discriminator is the mid-point of the steepest part on the saw tooth wave.

Figure 2 shows the essential features of the servo loop used in an analysis of the method of frequency stabilization.

The critical element is the error detector or frequency discriminator E. The output of the discriminator is proportional to an error frequency, which is the difference $(F_s - F_o)$ between a reference or set-point frequency F_s and the oscillator frequency F_o. In the discriminator, two distinct functions are performed. In the first place, the reference frequency is established, namely, that frequency for which the discrim-

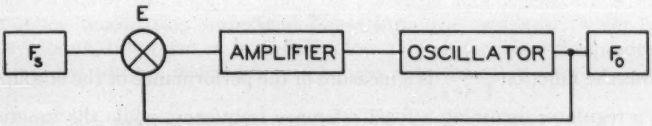

FIG. 2. Servo-loop used in analysis of frequency stabilizer.

inator output changes sign. The long term stability of the oscillator depends upon how well and with what degree of permanence the discriminator performs this first function. In the second place, the discriminator is characterized by a sensitivity—volts per megacycle—which among other factors determines loop gain μ. The ability of a stabilizer to protect output frequency against transient or short term disturbances depends upon loop gain. For the circuit of Fig. 2, the loop gain is given by

$$\mu = \frac{K}{1 + j\omega CR} \tag{2}$$

where K is a dimensionless constant and is the product of discriminator sensitivity, oscillator frequency sensitivity per control volt, and the amplifier gain. The manner in which μ varies with frequency is determined by a capacity C and resistance R used to limit gain at high frequencies. A servo pass characteristic of the type shown in Fig. 1 of course meets the Nyquist criterion for stability.

Two functions of μ, namely, $\frac{1}{1+\mu}$ and $\frac{\mu}{1+\mu}$, play a critical part in a description of the performance of the stabilizing system. If Δf_o represents a frequency change experienced by an unstabilized oscillator or oscillator followed by a multiplier due to an impressed disturbance such as a change in supply voltage, or to changes in temperature, the actual change which results with the feed back loop closed is

$$\Delta f_o' = \frac{1}{1+\mu}\Delta f_o = \frac{\Delta f_o}{S}, \tag{3}$$

where S is the stabilization factor.

The factor $\frac{\mu}{1+\mu}$ is used to calculate how well changes in the "set point" or reference frequency Δf_s are reproduced in the output frequency. The set point frequency is varied in resonant cavity methods by varying the resonant frequency of the cavity itself, or in the present method by varying the pass frequency of an intermediate frequency amplifier, or the gas frequency by use of a Stark field. For an impressed change in reference frequency Δf_s the resulting change in oscillator frequency is

$$\Delta f_s' = \frac{\mu}{1+\mu}\Delta f_s. \tag{4}$$

Thus the function $\frac{1}{1+\mu}$ is a measure of the performance of the stabilizer as a regulator assuming a fixed reference frequency, while the function $\frac{\mu}{1+\mu}$ is a measure of its performance as a "follow-up" system to changes introduced in the reference frequency.

Substituting Eq. 2 in (4) we obtain

$$\Delta f_s' = \frac{K}{1+K}\frac{1}{1+j\omega\dfrac{CR}{1+K}}\Delta f_s \simeq \frac{1}{1+j\omega\dfrac{CR}{1+K}}\Delta f_s. \tag{5}$$

Equation 5 shows that the speed of response of output frequency to changes in the reference frequency is determined by the time constant CR divided by loop gain rather than by the CR product itself. In general, the speed with which frequency is corrected is set by the effective time constant of the filter used with the discriminator and by the sampling rate. In the present system, the sampling rate is the limiting factor.

Here we encounter an interesting application of the uncertainty principle. The rate at which it is possible to elicit precise frequency information from a spectral line is limited by its band width. Thus in the present system, line width sets an upper limit to the interrogation rate, while in Pound's (3) cavity method the band-width of the cavity sets an upper limit to the frequency of the side bands which accompany an intermediate frequency to convey the error information. If we wish to increase interrogation rate and obtain information at a more rapid rate we may do so by increasing the gas pressure thereby increasing the line width, but as a result the mid-frequency of the line is now poorly defined. On the contrary, if we could increase Q so line width is say 10 cycles per second, the optimum interrogation rate is of the order of 10 per second, but the information obtained on line mid-frequency is exceedingly precise. Thus we cannot at once have both a high interrogation rate and highly precise information on the mid-frequency of a line.

It is sometimes desirable to modulate a stabilized oscillator. A method of wide band modulation may be based on simultaneous "set-point" and oscillator modulation. If we add Eqs. 3 and 4 we obtain a net frequency modulation Δf_n.

$$\Delta f_n = \frac{1}{1+\mu}\Delta f_o + \frac{\mu}{1+\mu}\Delta f_s. \tag{6}$$

Δf_o makes the dominant contribution to Δf_n at high modulating frequencies above the range for which the stabilizer acts degeneratively on frequency modulation impressed directly on the oscillator, while Δf_s is the dominating term at frequencies low enough for faithful reproduction in the output frequency of changes introduced in the set-point frequency.

If we now impose the restriction

$$\Delta f_o = \Delta f_s \tag{7}$$

Eq. 5 becomes

$$\Delta f_n = \Delta f_o = \Delta f_s. \tag{8}$$

The restriction in Eq. 7 may be satisfied by way of example in the present instance by introducing a change in some voltage which varies oscillator frequency such that in an unstablized oscillator the frequency change would be Δf_o, and *simultaneously* introducing an equal change in "set-point" frequency Δf_s by varying the tuning of the intermediate frequency amplifier by use of an appropriate reactance tube, or by use of a Stark shift in line position. Under these circumstances, no change in error frequency arises and hence no correction voltage, yet we have shifted frequency by the amount Δf_n to effect frequency modulation.

The performance of the present stabilizer, both short term and long term, may now be analyzed in terms of criteria used in discussing the behavior of servo-mechanisms. In the present equipment, K, the loop gain at frequencies such that $\omega < \frac{1}{CR'}$, is somewhat greater than 10^5. The discriminator sensitivity itself is of the order of 200 volts per megacycle, which incidentally is approximately 1000 times as great as that of microwave discriminators which employ some form of microwave bridge (3), energized by power from a microwave oscillator, and using opposed crystal detectors. In contrast, the present discriminator employs a moderate amount of amplification at intermediate and audio frequencies before the frequency comparison is made. With K equal to 10^5, a disturbance which would give rise to a 10 megacycle shift in an unstabilized oscillator is reduced by feed-back to less than 100 cycles. Short term stability of a stabilized oscillator may be kept high by two means: first, the use of adequate shielding, electrical, thermal, and other, to reduce to a minimum any disturbances which tend to cause a frequency shift and, second, the use of high gain in the feed-back loop.

Short term stability of 1 part in 10^8 or better has been reported for a number of stabilizing systems presently in use. The difference in performance between a stabilizer using a spectral line and one using a resonant cavity resides not in a significant improvement in short term stability as much as in realizable improvements in long term stability.

The long term stability of a stabilized oscillator depends on a number of factors which merit discussion. Of primary importance is the use of a standard which is reproducible, may be set up without referring to any other standard, is not subject to human "tinkering," and whose frequency is not affected by aging, and mechanical mishaps or deformation to which resonant cavities and quartz crystals are subject. However, the full advantages available by the use of a spectral line as a frequency standard may be lost in part in an ineffective discriminator. Discriminators whose "zero" is determined in a microwave bridge, itself frequency selective, or which employ opposing "matched" crystals are rather vulnerable on this score. In the present discriminator, the zero is set when we have time coincidence between two wave forms. Such coincidence owes its significance to the fact that the same spectrum analyzer—whose essential part is a swept microwave frequency—is used to compare two spectra, one characteristic of the gas line itself, and the second of the frequency being stabilized, or a frequency derived from the stabilized frequency by multiplication and addition. As a result the characteristics of the spectrum analyzer—power output, sweep width, and sweep rate—play a minor role in determining the zero of the discriminator.

Ultimate performance now depends on the ability of a coincidence or phase detector, together with the closed feed-back loop, to hold two wave forms in coincidence. When a narrow range sweep is used, as well as the same band width in the intermediate frequency amplifier as in the gas line, the two wave forms begin to resemble sine waves, and after filtering are sine waves in fact. The phase detector now in use is certainly able to distinguish phase differences which correspond to $\frac{1}{100}$ the width of a resonance curve which when taken in conjunction with line Q of 10^6, means that at present a long term stability of 1 part in 10^7 is realized. It should of course be pointed out that if n independent tuned L-C circuits determine the response of the intermediate frequency amplifier, the output voltage as a function of frequency is given by an expression of the form

$$\left(\frac{1}{\sqrt{1+\gamma^2}}\right)^n,$$

where γ is zero at resonance and is a measure of the frequency deviation from resonance. If the resonance curve is of the Lorentz type the cor-

responding expression is

$$\frac{1}{1+\gamma^2},$$

while if line shape is determined in part by collisions and in part by Doppler effect we have a line shape intermediate in form between one

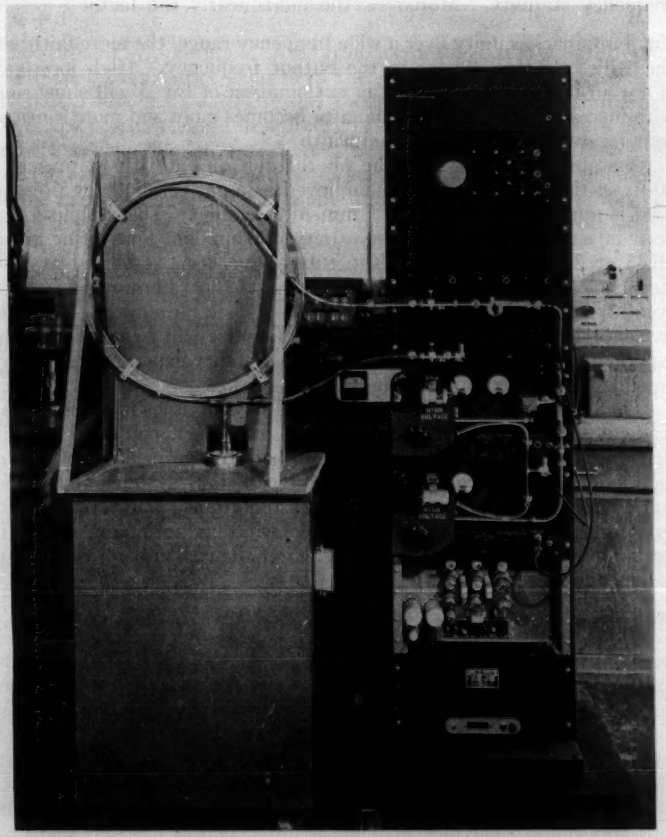

FIG. 3. Photograph of servo-stabilizer.

that is purely "Gaussian" and one that is "Lorentzian." These considerations serve to emphasize the advantages that arise in operating the system so "coincidence" is made to depend on the maxima of the response curves.

If at any point in a servo system for controlling frequency, such as in setting up a bridge balance, or determining a time coincidence, we are able to make an adjustment which shifts the zero of the discriminator, we have found a vulnerable point in the system such that inadvertent changes in this adjustment or noise at this point will adversely affect the frequency stability. Moreover, the more nearly the factor $\frac{\mu}{1+\mu}$ of Eq. 4 approaches unity over a wide frequency range, the more faithfully these disturbances appear in the output frequency. High loop gain is not an unmixed blessing as an examination of Eq. 5 will show since with increasing gain the discriminator becomes more and more sensitive to noise over an increasing band width.

A stabilizer is shown in the photograph of Fig. 3. At present a 30-ft. section of wave guide is employed as a gas cell and the pressure used is approximately 2×10^{-2} mm. of mercury. The stabilizer has been in use at K band with a variety of ammonia lines using either 2K33 or 2K50 tubes while 2K46 tubes have been stabilized at 7100 megacycles using a tripler and off-setting its third harmonic 15 megacycles from the (5, 3) ammonia line at 21,285.30 megacycles. Conclusive experiments or long term stability of course will require long term experiments while a variety of short term stability experiments are now possible with the equipments in use.

The question of long term stability of spectral lines is of more than academic interest. In the present state of the art, one need not differentiate between "dynamical" time (4) kept by aggregations of matter such as a pendulum, quartz crystals, or planetary systems and "kinematic" time kept by radiating molecules and atoms. However it is not unlikely that data from molecular clocks will play an important role in testing current hypotheses on the origin of the red shift of astronomy.

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RESEARCH FROM THE STANDPOINT OF THE SMALLER BUSINESS ENTERPRISE[1]

BY

G. H. CLAMER[2]

The present symposium is an outgrowth of a suggestion submitted to the Philadelphia District Council of the American Society for Testing Materials a few years ago. It was thought at that time desirable to explore the possibility and desirability of inaugurating a separate division of The Franklin Institute Laboratories for Research and Development for basic research in metals. This suggestion was later enlarged in scope to substitute the word "solids" for "metals." As a preliminary approach, suggestion was made that a symposium, under the joint auspices of the ASTM and The Franklin Institute be held.

The proposal to enter the field of basic research naturally anticipated a large investment for laboratory facilities and a still larger endowment for conducting the work. As basic research, except in a very limited field, is beyond the ability of the units of industry and the prospect of financial return is speculative, it was realized that the project could be undertaken only through group action and perhaps with Government assistance. In the meantime, under a well-organized effort and with the assurance of splendid facilities, this work will now be undertaken at the University of Chicago. The work is to be supported in a great measure by a group of large industrial concerns, to be known as the "Atom Club." The yearly dues for membership are $50,000 and membership of 100 is contemplated, thus giving a yearly budget of five million dollars. Notwithstanding this magnificent effort, basic research in limited fields is in progress at a number of laboratories.

The present symposium, contrary to the original suggestion, is to be confined to industrial research. I have been invited by your committee to participate, with the assigned subject, "Research from the Standpoint of the Smaller Business Enterprise." At this point it might be well to define "smaller business enterprise." The field, naturally, excludes the mammoth industrial groupings such as U. S. Steel, General Motors, General Electric, Westinghouse etc., but somewhere down the line there is a dividing point, not readily definable. For my own discussion I shall consider a smaller business enterprise as embracing all enterprise down to a single research worker; namely, the man who has a bright idea and proceeds to explore it, whether it be by means of equipment such as the

[1] Presented at the evening session of "Research for Management," a symposium sponsored jointly by the Philadelphia District Council of the American Society for Testing Materials and The Franklin Institute, held December 14, 1949, at The Franklin Institute.

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kitchen stove or a piece of apparatus in his cellar or attic. A number of the highly important discoveries have resulted through individual effort of that sort.

I at first hesitated in accepting the invitation of your committee to participate in this symposium, but later conceived the idea that it would perhaps be interesting and stimulating if I were to relate my own experiences in the field of research covering the period of the past fifty years.

I became associated with The Ajax Metal Company a little more than fifty years ago. The company at that time operated a foundry for the production of car and locomotive bearings and made a very limited tonnage of a bearing alloy in ingot form. The bearing alloy was essentially what has been known through the years, and still so designated, 80–10–10; namely, 80 copper, 10 tin, 10 lead. This alloy was made by merely melting the constituent metals and pouring the same into ingot molds or castings. A number of similar alloys were on the market, some containing phosphorus and all sold under trade names. Prior to the use of the 80–10–10 alloy a copper-tin alloy of 90 copper, 10 tin was

TABLE I.

Metal Tested	Copper, per cent	Tin, per cent	Lead, per cent	Phosphorus, per cent	Arsenic, per cent	Relative Wear
Phosphor bronze, standard	79.70	10	9.60	0.80	—	1.00
Ordinary bronze	87.50	12.50	—	—	—	1.49
Arsenic bronze, A	89.20	10	—	—	0.80	1.42
Arsenic bronze, B	82.20	10	7.00	—	0.80	1.15
Arsenic bronze, C	79.70	10	9.50	—	0.80	1.01
Bronze K	77.00	10.50	12.50	—	—	0.92
	77.00	8.00	15.00	—	—	0.86

used. It was found that the addition of lead to the copper and tin alloy gave it an unctuous property, thus reducing friction and at the same time reducing rate of wear.

Dr. Charles B. Dudley, first President and one of the founders of the ASTM was Chief Chemist of the Pennsylvania Railroad. Dr. Dudley was a research-minded individual. He was familiar with the fact that the addition of lead to the copper-tin alloy improved its properties as a bearing metal. Why, therefore, thought he, can it not be further improved by the addition of a higher percentage of lead? Thus was born the idea that led to extensive experimentation on the Pennsylvania Railroad under his guidance. These tests were conducted by inserting carefully machined and unlined car bearings in the journal boxes of cars used in regular service. In each case the bearing to be tested was placed on the opposite journal of the same axle on which the standard bearing was used. The placement of the bearings was as follows: Axle No. 1 phosphor bronze standard on the right end; test bearing on left end. Axle No. 2 test bearing on right end; standard phosphor bronze bearing on left end; alternating on the other axles in the same way. By this place-

ment of bearings there was, therefore, an equal number of standard and test bearings on each side of the car. Results of Dr. Dudley's tests are given in the paper he presented before The Franklin Institute in 1893. (See Table I.) Dr. Dudley summarized his conclusions as follows: "Rate of wear diminishes with the increase of lead and decrease of tin in the alloy." The higher lead and lower tin alloys exhibited less tendency toward overheating in operation. He was not able to carry his experiments beyond the 15 per cent lead alloy because as he stated, "Such alloys could not be commercially produced because of lead segregation."

One of my first ventures in the field of research was to acquire a knowledge of metallography. This I did by subscribing to the correspondence course in metallography sponsored by Sauveur and Boylston. Dr. Albert Sauveur, who had previously been with Cambria Steel Company, established a metallographic laboratory in Boston with Boylston as his assistant. Metallography was then in its infancy and had to be sold to metallurgists. Dr. Sauveur later became associated with MIT and finally headed the Department of Metallurgy at Harvard. Boylston later headed the Department of Metallurgy at Case School of Applied Science. Dr. Sauveur, as is well known, became internationally famous and was affectionately referred to as the dean of metallographists. He was recognized by The Franklin Institute by the award of the Franklin Medal and had many other honors bestowed upon him. It was a great privilege and a wonderful opportunity to have been tutored by this outstandingly competent and splendid man. It was through this early association that a friendship was established that was terminated only by his death. In addition to carrying on a consulting practice Sauveur and Boylston published a quarterly known as *The Metallographist*. It was possible through this publication to be informed of all the important metallographic work conducted in Europe. Little up to that time was done in this country.

CASE HISTORY NO. 1

I was naturally most interested in the alloys used for bearings. At the beginning of the century the copper-tin bearings had entirely disappeared from the market, having been supplanted by the alloys containing lead. As a result of the researches of Dr. Dudley lead in bearing alloys had been increased to 15 per cent and the tin reduced to 8 per cent. This was the alloy designated by Dudley as EXB metal. It was so designated because the alloy used for experiments designated as B were of the composition copper 77, tin 8, lead 15. This alloy is still largely used and is designated as Hard Bronze in AAR Spec. 503 and ASTM Spec. B66–46, Bronze Castings in the Rough for Locomotive Wearing Parts.

In *The Metallographist* there appeared a publication by Heacock & Neville showing the copper-tin constitution diagram. This gave me a clue. I was conversant with the fact that an addition of phosphorus to

these alloys formed a very low melting point eutectic alloy. I also learned through metallographic studies that lead almost completely segregated in the form of globules in the solidified alloy; namely, lead remained liquid in a matrix of copper and tin until it reached approximately the solidification point of pure lead. I reasoned that the way to hold the lead globules was to establish a matrix that would solidify at a high temperature and thus enmesh the lead before the globules had opportunity of coalescing and segregating to the bottom of the casting, or as the foundryman expressed it, "cause a lead sweat."

Study of the Heacock and Neville constitution diagram revealed the fact that under very carefully controlled slow cooling complete solidification did not occur in the alloy containing 10 per cent of tin until the temperature 1472° F. I found that the apparent solubility of tin in copper to form alpha solid solution in castings quickly chilled is in the neighborhood of 5 per cent and with a cooling rate such as occurs in commercial practice of making bearings in green sand molds about 7 per cent. Unfortunately, Dr. Dudley in all his experimental alloys had used an excess of phosphorus for deoxidizing purposes. In the alloy of experiment B there was a very large excess; namely, 0.25 per cent. The presence of that amount of phosphorus in the alloy greatly retards the solidification of the copper-tin matrix, thus giving abundant opportunity for the lead globules to coalesce and liquate, thereby producing, as Dudley stated, defective castings.

My researches were directed toward reducing the tin content and entirely eliminating the phosphorus, thereby obtaining a quick setting matrix. The experiments were continued by increasing the lead content beyond 15 per cent and decreasing the tin content below the 8 per cent of Dudley EXB alloy and avoiding the use of phosphorus as a deoxidizer. It was found that good castings could be produced with an alloy containing up to 7 per cent of tin and up to 20 per cent of lead. It was further found that by decreasing the tin content to 5 per cent a lead content of 30 per cent was possible without liquation. These high lead alloys have found wide use for bearings. (See Table II.) They are gen-

TABLE II.

	Copper, per cent	Tin, per cent	Lead, per cent	Friction	Temperature Above Room Temperature, deg. Fahr.	Wear, g.
1	85.76	14.90	—	13	50	0.2800
2	90.67	9.45	—	13	51	0.1768
3	95.01	4.95	—	16	52	0.0776
4	90.82	4.62	4.82	14	53	0.0542
5	85.12	4.64	10.64	18½	56	0.0380
6	81.27	5.17	14.14	18½	58	0.0327
7	75?	5?	20?	18½	58	0.0277
8	68.71	5.24	26.67	18	58	0.0204
9	64.34	4.70	31.22	18	44	0.0130

erally referred to as Plastic Bronze and are designated as Soft Bronze in AAR Spec. M–503 and ASTM Spec. B66 for Bronze Castings in the Rough for Locomotive Wearing Parts and as alloy 3E within the class of High Leaded Bronzes of Spec. B30 ASTM, Copper Base Alloys in Ingot Form for Sand Castings, also SAE-AMS Spec. 4822A.

CASE HISTORY NO. 2

Insofar as I have been able to discover, I was the first chemist regularly employed in an industry devoted to the production of copper-base alloy products, either cast or wrought. It was a decided advantage to be engaged in what might be termed a virgin field. Naturally, the first thought a chemist would have, aside from making chemical analyses for control purposes, would be to apply his chemical knowledge to effect economies.

Drs. Greene and Wahl had in 1893 patented the aluminothermic reduction method. Dr. Wahl was secretary of The Franklin Institute and Dr. Greene headed the chemistry department at the Philadelphia Central High School. Their experiments were conducted in the laboratory at the old Franklin Institute building on Seventh Street near Market. In one of their experiments, to their amazement, they discovered the enormous heat of reaction between aluminum and an easily reducible oxide; namely, an explosion resulted wrecking their furnace.

Hadfield's manganese steel was then on the market. It was described as hard, tough and non-machinable. It was non-machinable with the tool steels of that day. Greene and Wahl believed that it would be possible to produce Hadfield's manganese steel that would be hard, tough and machinable, if carbon was eliminated. Being familiar with the relative heats of formation of manganese and aluminum with oxygen, they concluded that aluminum could be used as the reducing agent and a carbonless manganese would result. Their experiments proved this to be a fact. A mixture of granulated aluminum, manganese oxide and a flux was raised to the reaction temperature in a furnace in which the charge had no contact with carbon. When the reaction temperature was reached the reaction proceeded with great rapidity. It was not until many years afterward that Goldschmidt discovered that the aluminothermic reaction could be conducted at atmospheric temperature by raising a small portion of the mixture to reaction temperature by a mixture of magnesium powder and a compound that would readily give up its oxygen Thus was born the so-called "thermit process" in extensive use today.

Aluminum at that time was an expensive metal. Greene and Wahl, therefore, sought a cheaper reducing agent. They found this in silicon. The high silicon ferro alloys were not yet on the market so they had to be content with using spiegeleisen. Spiegeleisen, of course, was not free of carbon but it was low in carbon and gave a satisfactory product.

Being on the alert for finding new alloys we took an option on the Greene and Wahl patents and did considerable research work in connection therewith at the plant of the Cowles Electric & Aluminum Co. at Lockport, N. Y. We there had the advantage of using an arc type electric furnace in which our charges could be brought to the reaction temperature and in which additional heat could be applied if necessary to bring the charge to a sufficiently liquid condition to cast. A fair amount of ferro-manganese and ferro-chromium was made and small batches of ferro-tungsten and ferro-molybdenum. We dropped the project because the alloy steel era had not yet begun and we found little demand for our products. Later Greene and Wahl sold their patents to the Wilson Aluminum Co. That company, in turn, was absorbed by the Union Carbide Co. and the Greene and Wahl process, improved upon by them, was used to a tremendous extent by its division, later known as Electro Metallurgical Division.

Although Greene and Wahl had published an account of their experiments, no one had apparently thought of applying the same type of metallurgical reactions in the copper-base alloy field. In the manufacture of locomotive bearings the copper-tin-lead alloys were strictly adhered to, but car bearings were at that time, as at present, universally lined with a lead-base alloy. So long as the lining remained intact it was merely necessary to provide a backing of sufficient strength to perform satisfactorily in service. The presence of zinc in the back of the car bearing increased the rate of wear as shown in Table III. Perhaps

TABLE III.

	Copper, per cent	Tin, per cent	Lead, per cent	Zinc, per cent	Friction	Temperature Above Room Temperature, deg. Fahr.	Wear, g.
5	85.12	4.64	10.64	—	18½	56	0.0380
10	83.27	5.28	10.25	2.07	18½	68	0.0415
11	79.84	4.71	10.30	5.44	18½	66	0.0466
12	77.38	5.62	11.42	6.54	18½	68	0.0472
13	74.28	4.68	10.61	11.04	18½	69	0.0846

90 per cent of the car bearings that did not fail due to a hot box were rejected because of excessive end or collar wear. To obtain maximum service it was, therefore, desirable to increase the lead and reduce the tin and zinc as far as practicable.

There were large accumulations of copper-base alloy scrap at low price on the market because methods of utilizing the same to best advantage were not yet known. Brass and bronze scrap was a heterogeneous mass of individual pieces, predominantly of copper and containing varying percentages of tin, lead, zinc, and a relatively small percentage of iron. If the zinc and iron could be eliminated or sufficiently reduced, copper, tin and lead, the three valuable constituent metals of the bearing

alloy, would remain. The heat of formation of both zinc and iron with oxygen is greater than either tin, lead or copper. Profiting by the knowledge gained through my contacts with Greene and Wahl I concluded that the easy and economic way to reduce these two undesirable elements was to melt a batch of miscellaneous scrap, make a bath analysis, and then treat the same with a calculated amount of the oxide of either copper, tin or lead, or mixtures of the same. Such oxides were on the market as cheap by-products in the form of tin, lead or solder dross and copper oxide was available as mill scale resulting from the rolling of copper sheets. The oxides naturally were suspended in a fusible slag.

Later we found it more profitable to discontinue the manufacture of car and locomotive bearings and concentrate on the production of ingot metal, using the described process. It was possible to produce alloys of copper, tin, lead or copper, tin, lead, and zinc to rigid chemical specifications and sell profitably such ingot at a price attractively below the cost at which the same mixtures could be made from virgin metals.

The ingot industry has grown in the last fifty years from a very small beginning. It reached its peak during the recent war with an output of 500,000 tons (one billion pounds). It is estimated that the normal peacetime demand is in the neighborhood of 300,000 tons (six hundred million pounds). In dollar value the output fluctuates widely with the fluctuation in the price of metals. An estimate of the normal dollar value in peacetime is 100 million dollars. At present there are about fifty producers, large and small. Fifteen of the larger producers account for half of the output and the balance is distributed among the smaller producers. The output of ingot manufacturers has been standardized and a great portion of the same is sold under ASTM Spec. B30–48. Producers have no difficulty in meeting the imposed tolerances and maximum limitation on impurities.

CASE HISTORY NO. 3

In the beginning of the second decade of the present century much attention was given to the problem of zinc losses in the brass industry. Attention was focused on this problem, particularly by Dr. Parsons, who was then Director of the Bureau of Mines. It was variously estimated that the zinc loss per day up the stacks of the rolling mills of Waterbury, Conn. was from 10 to 15 thousand pounds. The zinc oxide settled over the city and became a matter of municipal concern. Using Waterbury figures as a basis, the zinc losses in the entire country were no doubt upwards of 50,000 pounds per day.

Professor Turner of the University of Sheffield, England, published a paper about that time reporting laboratory experiments covering fractional distillation of zinc from copper-base alloys in vacuum. Dr. Carl Hering, one of the founders of the American Electrochemical Society and a past-president thereof, also a past-president of the American Institute of Electrical Engineers, was an active member of The Franklin

Institute. He had discovered and named the "pinch effect." Pinch effect occurs in a conductor of liquid metal when the current density exceeds a certain degree; viz, the column of metal constricts as if it were pinched, hence, the name pinch effect.

Hering proposed to utilize the pinch phenomenon in the construction of an electric furnace. Briefly, the furnace is of the resistance type. The metal is heated like the filament of an incandescent lamp by passing the current through a column of liquid metal. The furnace itself consists of a hearth having two, three or four cylindrical holes in the bottom, closed at their far end by electrodes (Fig. 1). By means of the elec-

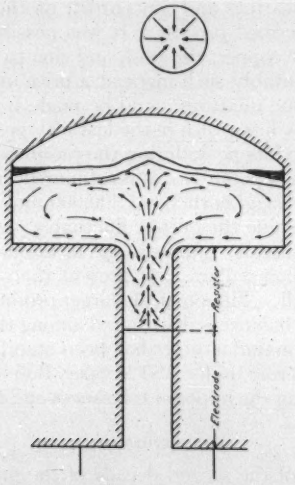

FIG. 1. Hering Furnace, showing cross section of a single electrode resistor connected with bath and direction of circulation.

trodes the electric current passes through the columns of metal in these holes and is short-circuited through the bath, thereby heating very rapidly. The proportions are made such that all the heat of the furnace is generated in the metal in these tubes. In addition to thus heating the metal the current exerts the pinch force by means of which it circulates the metal very rapidly in these holes by forcing it out into the bath and sucking liquid metal into the holes, hence the heat which is generated in the holes is rapidly transmitted to the bath of metal in the hearth. The action is essentially that of an electromagnetic pump, which not only circulates the metal as it becomes hot in the tubes, but causes circulation in the bath as well.

Hering presented his ideas to me. Having fresh in my mind the current discussions re zinc losses and the work of Prof. Turner, I was sufficiently interested in Hering's disclosure to influence my company in undertaking the development and exploitation of such a furnace. Prior to that time all research and development was undertaken by me personally but from henceforth the researches which I will later describe were results of group effort.

On paper the Hering furnace was quite simple and its performance subject to physical laws. My allotted time does not permit of any details, but the following was the conclusion after the expenditure of much effort and funds: The Hering furnace was a failure because of the following difficulties encountered:

(1) Maintaining a sealed furnace that was dependent upon embedding large water-cooled electrodes in a refractory material. (Metal and refractory have widely different coefficient of expansion.)
(2) The great volume of water required to prevent melting of electrodes. By actual test 50 per cent of the heat units applied were lost in the water.

Notwithstanding the failure of the Hering furnace we had gained largely in experience. We definitely learned that the source of all the trouble in the Hering furnace was the use of electrodes. Why not eliminate them, we argued, by turning it into an induction furnace? To do this all that was necessary was to eliminate the electrodes, join the two columns of liquid metal and thread a transformer through the loop.

Horizontal ring type induction furnaces were in use in the steel industry and had been tried experimentally for melting brass. The experiments in melting brass resulted in failure because of the pinch effect I have previously referred to. Our proposal was merely to turn the horizontal ring at an angle or in a vertical position and connect it with a bath sufficiently deep to impose the necessary hydraulic head.

Thus was born the idea that resulted in the wide commercial use of the submerged resistor induction type of furnace. (See Figs. 2 and 3.)

James R. Wyatt was one of the group working with Carl Hering on the development of the pinch effect furnace. As I have stated, one of the perplexing problems was to prevent by water cooling the melting of the metallic electrodes used. Non-metallic electrodes were out of the question because of the tremendous amperage required. Many designs of electrodes were experimented with, mostly hollow and filled with refractory material. Hollow forms were necessary because of "skin" effect. Hering opposed the induction furnace idea because he believed it would be impossible to eliminate the heat generated in the long secondary circuit at a sufficiently rapid rate to be practical.

While experimenting with electrodes that became partially molten

FIG. 2. Ajax-Wyatt Submerged Resistor Induction Furnace with v-shaped resistor showing direction of metal circulation.

FIG. 3. Ajax-Wyatt Submerged Resistor Induction Furnace (Foley type) u-shaped secondary.

and in which the current path took an angle Wyatt observed that at the angle much motion of the liquid conductor was produced. This he reasoned was due to motor effect caused by the field on one side of the angle opposing the field on the other. As a result of this observation our research group was divided; Hering and his associates continuing experiments on his electrode type furnace and Wyatt with his group devoting their attention to the development of a submerged resistor induction furnace.

Without attempting to here go into detail, it soon became evident that the Hering group had little, if any, chance of overcoming the tre-

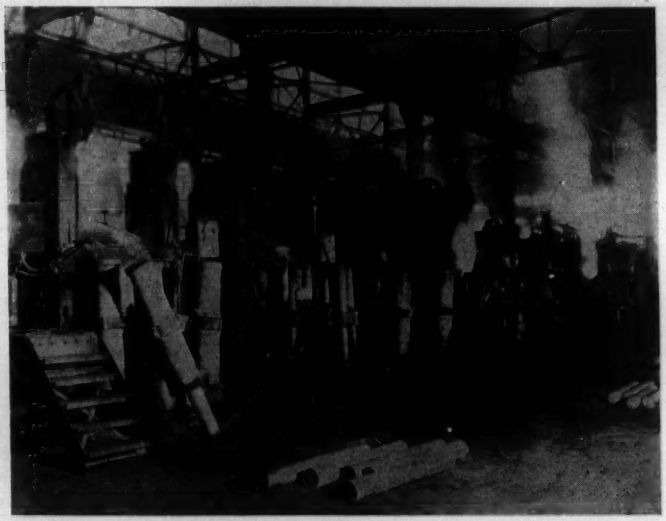

FIG. 4. Casting extrusion billets from metal melted in Ajax-Wyatt Submerged Resistor Induction Furnaces.

mendous obstacles encountered. Wyatt with his group, on the other hand, soon demonstrated the practicality of the idea. With an up-ended v-shape molten metallic resistor connected with a bath to establish sufficient hydraulic head it was possible to induce current of such magnitude in the secondary circuit that the metal was not only rapidly melted but also rapidly ejected with a minimum of overheating. In the submerged resistor type induction furnace advantage is taken of three powerful means for circulating the metal; namely, convection, pinch effect and motor effect.

The demonstration of the first furnace of the induction type was made about the beginning of World War I. In a short time it was

sufficiently perfected for practical use. It immediately attracted great attention on the part of brass mill operators. At that time practically all brass was melted in clay-graphite crucibles. Klingenburg clay was an imported product, as was also a large part of the graphite used in crucible manufacture. As the war progressed these supplies were practically cut off and crucible manufacturers had to resort to the use of domestic clay and graphite with the result that very inferior crucibles were produced. The matter became critical and the submerged resistor type of furnace, which became known as the Ajax-Wyatt, was rapidly adopted.

FIG. 5. Casting slabs from metal melted in Ajax-Wyatt Submerged Resistor Induction Furnaces.

It was naturally not all plain sailing. Many hurdles were encountered and had to be overcome. These were especially in developing durable linings, means for preventing the incrustation of the secondary channels, and in general developing the most satisfactory designs. A tremendous amount of research work has been devoted to these ends and still continues.

The Ajax-Wyatt type of furnace caused an almost complete revolution in the melting methods used in the wrought brass industry. Only a few of the old type melting equipments are today used. This revolution proceeded not only in this country but in practically all foreign

countries where brass for the making of wrought products is melted. (See Figs. 4 and 5.)

CASE HISTORY NO. 4

The submerged resistor type of furnace has as its principal drawback the requirement that the metal in the resistor channel and a bath with sufficient hydraulic head above it must be continuously kept molten or for intermittent operation poured and the furnace re-started with molten metal from an exterior source. This limitation precluded the use of this type of furnace for intermittent melting or for melting alloys of widely varying composition. Recognizing this limitation, Dr. Edwin F. Northrup, then of the Palmer Laboratory at Princeton University, was retained and given the following assignment:

> "Is there a basic principle for electric heating that has been overlooked and that can overcome the limitations of the submerged resistor induction furnace?"

Dr. Northrup, after a careful study of the methods used for electric heating, reported that there was but one possibility; namely, heating with high frequency currents. By using high frequency currents the usual magnetic core threading the primary and secondary could be eliminated. Dr. Northrup was retained to make some preliminary experiments to demonstrate the basic principle of high frequency heating. No equipment other than the rotary spark gap and very inadequate condensers for power factor correction was then available. He succeeded by means of a crudely designed rotary spark gap and still more crudely designed glass and sheet brass condensers, to demonstrate that heat can be generated within a bath of metal. This he did by melting about a thimbleful of tin in a crucible of correspondingly small capacity. Dr. Northrup and two of his students became our research group to continue the further development of the high frequency method of heating. This original group was later succeeded by Messrs. Blakeslee, Meyer, Chestnut, Applegate and Kennedy.

Only a few laboratory equipments were developed and sold in the first eight years after the initial experiments. We were, however, able to convince ourselves and also the General Electric Company and Westinghouse Electric Corporation that the high frequency method of heating presented an attractive field for commercial exploitation. The interest of these companies was sufficiently great to induce their respective managements to develop motor driven high frequency generators and condensers for power factor correction such as needed for the frequencies later used; namely, one to two thousand cycles. The first such equipment (100 kw.) was installed in our own laboratory. With this equipment available for demonstrating purposes contracts were at first slowly acquired and as the use in the field extended orders came in at an

accelerated rate. Our first endeavors were directed to melting metals and this was later expanded to cover many heating operations without melting, and particularly for selective heating for hardening.

The high frequency furnace has been exploited under the name Ajax-Northrup High Frequency Furnace. A sectional view of furnace showing the magnetic field and stirring action of the molten charge is shown in Fig. 6. It would appear from this drawing that the furnace is of

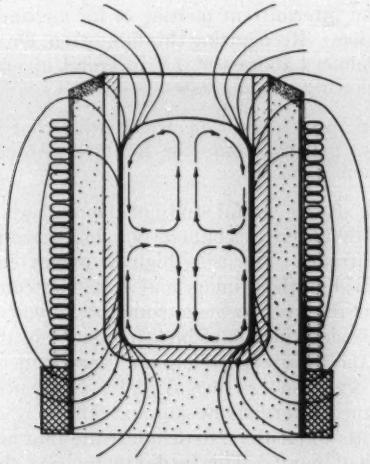

FIG. 6. A sectional view of Ajax-Northrup High Frequency Induction Furnace showing the magnetic field and stirring action of the molten stage.

utmost simplicity. As a matter of fact it is, but notwithstanding, it took years of research and development and the expenditure of approximately two hundred thousand dollars to bring it to the stage for dependable commercial use. The Ajax-Northrup High Frequency (or coreless induction) Furnace is really an air cooled transformer, whose primary is the furnace coil and whose secondary is the melt or other conducting body to be treated. The primary is a helical coil of copper tubing insulated between turns, through which water is passed for cooling purposes. When high frequency current is applied to the terminals of the helix all the space inside the coil is subjected to a rapidly alternating electromagnetic field. Any electrical conductor inside the coil (in this case the furnace charge) has currents induced in it. These induced currents cause rapid heating up to and beyond the melting point. The same principle applies to heating below the melting point for forging, brazing, annealing or hardening.

It is evident that conducting bodies can be heated in a vacuum as well as in air. Recognition of this fact led to one of the early extended uses of the coreless high frequency method of heating; namely, for heating the metallic parts within vacuum tubes to drive out the contained gases when tubes are being evacuated. It was only by reason of this method that the vacuum tube for its many and diversified uses was brought to the required stage of perfection for satisfactory use. This same accomplishment, namely, not only heating but melting in a vacuum, has led to a number of important discoveries and made possible the melting of uranium for casting the sticks used in the atomic pile. Many of these furnaces were used for the Manhattan Project.

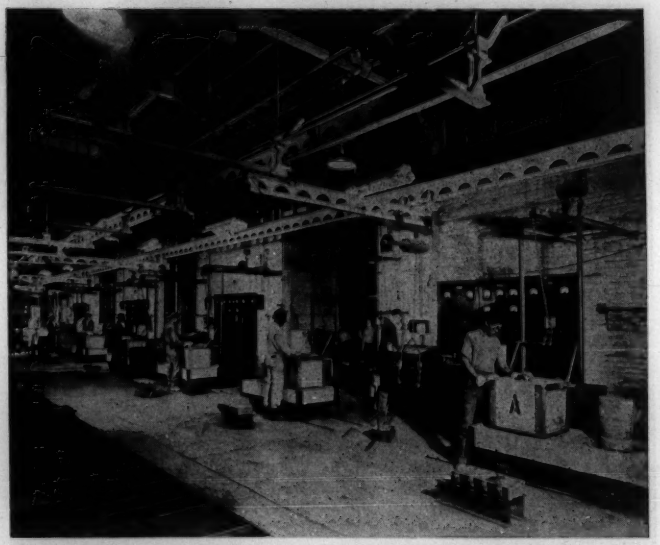

FIG. 7. Ajax-Northrup High Frequency Induction Furnaces—lift coil type—showing battery of furnaces used in foundry making small bronze castings.

The high frequency furnace has been particularly useful in producing high alloy steels and other difficult alloys. The largest melting unit in use has a hearth capacity of 8 tons and is powered with 1800 kw. It is in extended use for heating billets for forging, hot pressing, etc., and for innumerable surface hardening operations. By using very high frequencies it has come into extended use for dielectric heating of non-metallic substances. It is in extended use in all the industralized countries of the world. Although a monopoly was enjoyed during the life

of the basic patents and sub-licenses granted, since the expiration of the patents a veritable industry is now engaged in exploiting high frequency equipment. (See Figs. 7 and 8.)

CASE HISTORY NO. 5

Aluminum being a metal of relatively low melting point, coupled with high specific heat and high latent heat of fusion, melting with electric power would not seem to hold much promise from the economic viewpoint. It was this fact that deterred interest in electric melting of aluminum for many years. Attempts had been made to melt aluminum in different types of electric furnaces, including induction furnaces. In

FIG. 8. 7000 kw. of Ajax-Northrup Heaters at plant of Mullins Mfg. Co., Salem, Ohio, for heating bar stock for shell forgings. Rated production: 1060 shells per hour.

the submerged resistor induction furnace it was discovered that the channels of the secondary circuit became rapidly incrusted with aluminum oxide. The aluminum oxide incrustation was found to contain some aluminum nitride. The incrustation will take place even although the surface of the bath is protected by a reducing medium. The reason for the incrustation has never been satisfactorily explained. As the incrustation increased the power input was correspondingly reduced and finally to such degree that operation was no longer satisfactory.

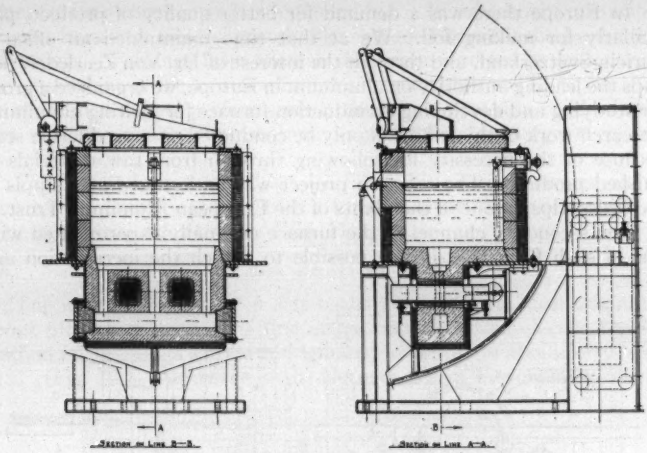

FIG. 9. Ajax-Tama-Wyatt Induction Furnace with straight, easily cleaned induction channels.

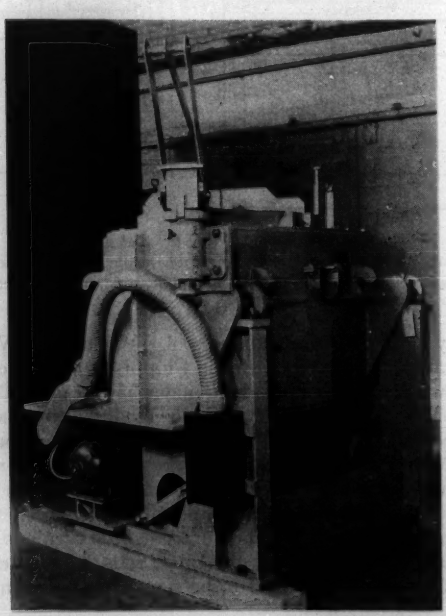

FIG. 10. Photograph of Ajax-Tama-Wyatt Induction Furnace.

In Europe there was a demand for better quality of product, particularly for making foil. We at that time maintained an office in Zurich, Switzerland, and through the interest of Dr. Von Zeerleder, perhaps the leading authority on aluminum in Europe, we organized a group for studying and developing an induction furnace for melting aluminum. Research work of this kind can only be conducted on a production scale because of the necessity for following through from raw materials to finished product. The research project was undertaken at Chippis in the Swiss Alps, at one of the plants of the European Aluminum Trust.

The secondary channel of the furnace originally experimented with was of such form that it was possible to detach the incrustation and

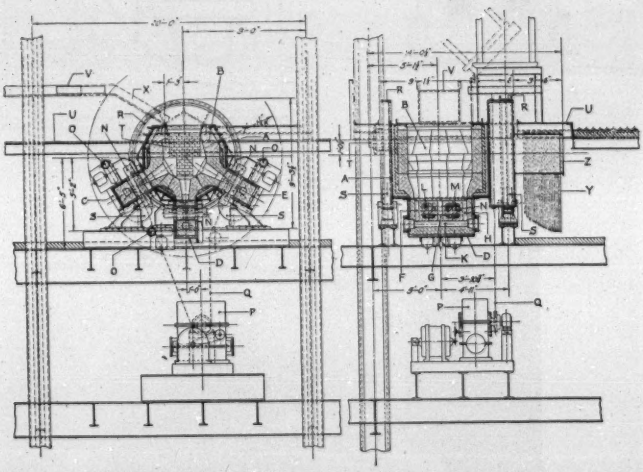

FIG. 11. Ajax-Scomet Furnace—1000 kw.—10 tons holding capacity—melting rate 10,000 lb. per hour—in use at the most modern brass mill in the world, put into operation by Scovill Manufacturing Co., Waterbury, Conn. in 1949.

eliminate it by means of an articulated tool. When World War II began our representatives connected with the Chippis group came to America and research work was continued here under Mr. Manuel Tama and his son, Mario. We finally evolved a furnace of simplified construction in which the tubes could be cleaned by poking a bar down through the bath into them. Many furnaces of this type are now operating with utmost satisfaction in many parts of the United States and Canada and in some other foreign localities. (See Figs. 9 and 10.)

In this furnace hundreds of tons of extruded rod turnings were melted during the war and cast into 2½ in. 12 ft. rods. The metallographic structure of these rods was found to be somewhat between the normal

structure for a cast bar and an extruded bar. In subsequent operations the cast bars were treated exactly like extruded bars for the production of forgings. Forgings from the cast bar were reported to be in every way equivalent to the forgings from the extruded bar. The explanation for the structure and performance of these bars probably resides in the fact that the metal, after melting, is subjected to energetic electromagnetic stirring.

The largest furnaces of this type for melting both brass and aluminum have a hearth capacity of ten tons. Larger units are possible if there is a demand for them. (Fig. 11.)

CASE HISTORY NO. 6

The idea of using molten salt baths for hardening steel originated about fifty years ago. The first suggestion to use an electric heating method for melting a salt bath originated in Germany about forty years ago. (Fig. 12.) A furnace of the German design was exploited in this

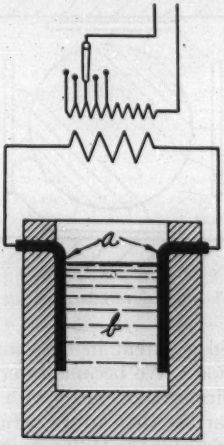

FIG. 12. Early German electrode type salt bath furnace.

country by the General Electric Company. The furnace took the form of a square or oblong molten salt container made of firebrick slabs. Two iron electrodes, located on opposite sides of the crucible, directed the current from the transformer through the bath. Salts used for the bath are poor conductors of current when cold. For starting it was necessary to melt a trough extending from one electrode to the other in the solidified bath. For that purpose an auxilliary rod form electrode and fragments of standard lamp carbon were used. Contact was made between the auxiliary electrode, the pieces of carbon and the bath electrode on

the left. This caused a circuit of sufficient resistance to melt a trough of salt. The auxiliary electrode was then moved to the right until molten salt completed the circuit between the two bath electrodes. From then on the entire bath is gradually melted.

In a furnace of this construction the work load must of necessity be placed directly in the current path between the two electrodes. The metallic pieces to be heated having higher conductivity than the bath produced a path of least resistance to the current flow, with a consequence that uneven heating resulted. (Fig. 13.) Because of that drawback this furnace was little used. To overcome this defect Professor Axel Hultgren of the Royal Technical Institute in Stockholm conceived the idea of using a pair or pairs of electrodes removed from the area in which the metallic pieces to be heated were placed. This arrangement has the further advantage of being applicable for single or multi-phase operation. (Fig. 14.)

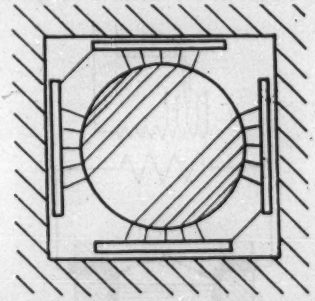

FIG. 13. Electrode salt bath with large milling cutter immersed.

Hultgren was granted a patent in USA and other countries for a furnace of his construction. We became interested in the patent and concluded an exclusive license agreement with Hultgren. He had not at the time progressed farther than to use a furnace or two in his own laboratory. To further develop the Hultgren invention a research group that had had extended experience with our induction furnaces was given the assignment under Mr. William Adam, Jr., and Mr. John E. Haig. They knew a lot about electro-dynamic circulation from their experience with induction furnaces. They soon discovered when a pair of electrodes in molten salt were brought into close relationship under proper current conditions a forceful downward flow of molten salt between the electrodes was produced. This flow is opposite to the direction of flow that might be obtained from thermal convection. This extremely active circulation literally takes the heat away from the electrode area as fast as it is generated. Just as in the submerged resistor induction furnace

heat is carried out of the inductor channels by the forces of pinch pressure and motor effect.

Figure 15 illustrates the theory of electro-dynamic circulation. Maxwell's well-known Law of Electromotive Force states that any conductor

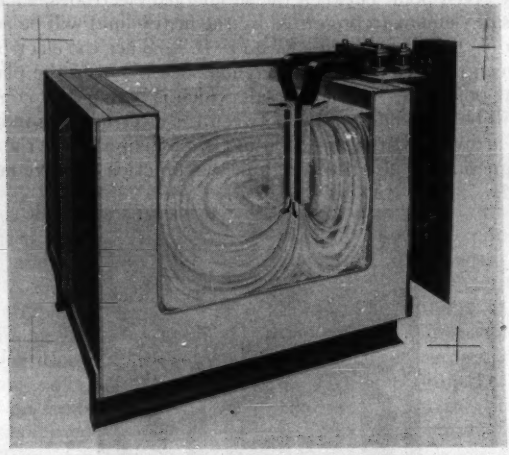

FIG. 14. Electrodynamic circulation produced in Ajax-Hultgren design, showing downward flow of liquid salt created in the electrode gap by virtue of the current flowing from electrode to electrode reacting with a heavy magnetic field passing through the electrode gap created by the heavy current flowing in the electrodes.

that carries current, when placed in a magnetic field, tends to move at right angles to the direction of the magnetic field . . . and at right angles to the direction of the current. Applying this rule to the salt bath, electrodes "A" and "B" are immersed vertically and close together

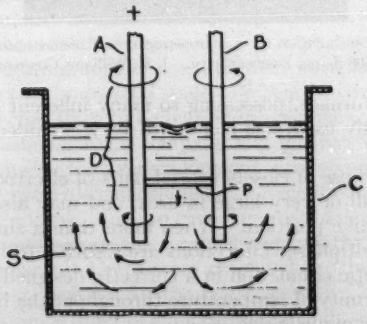

FIG. 15. Theory of electrodynamic circulation in Ajax-Hultgren furnace.

in a molten salt "S." A current of high magnitude, 3000 amperes for example, is passed between them. Each electrode is surrounded by approximately circular lines of force "D." Current of high density flows between the electrodes at all points below the surface of the bath.

At any given point between the submerged electrodes, such as point "P," the salt element (represented by the heavy line) will be acting as a conductor of current between "A" and "B." Since the electromagnetic field between the two electrodes extends outward from the plane of the drawing at point "P," the liquid salt which is acting as a conductor of current will be forced *downward* between the electrodes, as indicated by the black arrows. If the direction of current is reversed, the direction of the magnetic field also reverses, and the direction of movement is still downward.

FIG. 16. Mechanized installation for austempering miscellaneous open end, adjustable and socket wrenches, 500 lb. per hour capacity. J. H. Williams Company, Buffalo, N. Y.

This type of furnace, possessing so many inherent advantages over furnaces previously used, has come into very extended and diversified use.

Because of the use of closely spaced pairs of electrodes the salt bath may be very small or very large in area, and may also be placed in a vertical or stack-like position. When more than a single pair of electrodes is used multiphase connections are resorted to. Because of the active and energetic circulation in a correctly designed furnace there is remarkable uniformity of temperature throughout the bath, usually not more than plus or minus 5 deg. F.

Mr. Leon B. Rosseau was subsequently added to our staff and offered many valuable suggestions. (Fig. 16.)

In my paper I have discussed six case histories. Each of the referred to projects was the result of invention. Hundreds of lesser projects have been engaged in, mostly tied in with the six projects referred to. Many projects produced negative results. These, however, had their value, influencing intelligent elimination and often indicating the direction in which success was finally achieved.

Project No. 1; namely, the development of a high lead bearing alloy, and Project No. 2, a method of refining copper-base alloys, had to do with the non-ferrous metal industry in which our parent company has been so long engaged. The original patents expired early in the present century and have since been used extensively in the entire industry.

Project No. 3; namely, development of the submerged resistor induction furnace, resulted through a desire to develop an equipment that would be useful in our metal business. There is a Chinese proverb as follows: "No matter how long the journey the first step must be taken." The first step in this instance was an agreement with Dr. Carl Hering to underwrite an expenditure of $500 for an experiment to use pinch effect for the operation of an electric furnace. The initial experiment was no more than sufficient to demonstrate the workability of the idea. We were led on from experiment to experiment and by the time we had spent $40,000 came to the conclusion that the electrode type, pinch effect furnace, for the reasons I have stated, was impractical. This is an outstanding example of an experimental venture leading to a negative result, and I can assure you that the $40,000 expenditure was very much of a headache at the time, but as it later turned out was a very valuable investment because it pointed the way to the development of a practical furnace using electromagnetic forces to circulate liquid metal. After the Hering water cooled electrodes were discarded and our future work confined to the induction furnace, it still required the expenditure of about $200,000 before a commercially satisfactory unit was developed.

The developments described under case histories Nos. 4, 5 and 6 were by-products of these original researches. In each case there was a main invention. Separate groups of research men were assigned to develop the invention to the commercial stage. When the equipment reached a sufficiently perfected stage to be marketable a separate or division company was established. Each company was incorporated and the main employees responsible for the development were given stock in the Corporation. They were also made officers. Except in one case the parent company took Preferred Stock to cover the cost of development and the initial amount involved in the establishment of the business; viz, for plant and equipment. Loans were extended by the parent company in lieu of working capital. In the one case only Common Stock was issued because a single order of sufficient magnitude was obtained before

the company was organized to provide the financial means to get under way. In this case only loans were extended.

At the present time these companies have not only been able to liquidate the Preferred Stock, thus reimbursing the parent company for the original outlays, but have paid dividends on the Common Stock and have built up their resources to the extent that they are now able to carry on, seldom requiring outside financial assistance. Each company now has a splendid plant, fully equipped and manned to meet their sales demand. The equipment in service throughout the world resulting from our researches requires for operation a powerhouse load of over a million kilowatts.

The plan we have followed, although not entirely new, is unique and its effectiveness has been amply proved by the success attained. The research workers have been amply rewarded and have been stimulated by the incentive of stock ownership, official participation and liberal bonuses based on earnings. Our plan is ample proof of the advantages accruing under private enterprise and the capitalistic system.

All the research projects I have thus far referred to were conducted in our company laboratories and works. Much of the work had to be conducted on a commercial scale. There are many problems and many ideas, some of which amount to invention, frequently brought to the attention of the management of the smaller business enterprises. Many of the problems can be more satisfactorily solved and the inventive ideas developed by institutions operated on a non-profit basis such as Battelle, Mellon and The Franklin Institute. These institutions are staffed and equipped on a scale beyond the possibilities of the smaller business enterprises. Some problems are perhaps best handled by smaller private research companies and colleges.

For many years I have acted as chairman of committees for groups sponsoring research. The Brass and Bronze Ingot Institute, in which our parent company holds membership, has financially sponsored and supervised researches on copper-base alloys for sand castings. These researches are primarily conducted for the benefit of the consumers of ingot metal; viz, its customers, the brass foundrymen. This sponsored work I am confident has created a degree of good will and prestige for the ingot institute that would not have been possible by the expenditure of a far greater amount for space advertising. I offer here the suggestion based on experience that group sponsorship of research projects offers a fertile field.

Before closing I shall quote from an article by Samuel T. Williamson that recently appeared in *Barron's:*

> "Almost every big business one can think of started small. Small business is the hope and beneficiary of competitive enterprise. As long as there are people who would rather work for themselves even

if it means working harder, and as long as small units can do some things better and cheaper than big ones, small business has a future. As long as competition is free and fair it need not fear big business.

"Business freedom may be measured by these questions: Are people free to invent new devices, to bring out new products, to organize new services? Can people buy what they need from more than one producer or seller? And are the producers and sellers operating on a competitive basis? If so, small business—any business—is free.

"Small business is the freest segment of U. S. Economy and the strongest bulwark against a managed one. It is not so tightly regulated as big business or even big labor. A Senate committee described it well: 'Small business is the major source from which our private-enterprise economy is supplied with new blood.' "

I can testify from my own experience in the field of research that it has been an interesting, exciting, happy and profitable experience.

Music Lessons by Electronics.—The Monarch Conservatories of Music in Hammond, Indiana, are utilizing a new method of teaching that brings music lessons into the electronic age—making it fun instead of a chore and taking most of the drudgery out of practice. The result is progress about 50 per cent faster for the students using the system.

It's called the "electronic memory" method and it involves making a wire recording of every moment of each lesson, so the student can take it home to play over and over as a guide in his practice sessions. Not only does he have all the instructions and demonstrations of the teacher whenever he wants them, but his parents can listen and help him with his practicing. And the fun of handling the wire recorder—and the dozens of other ways it can be used around the home—appeal to the exploring urge of youth.

Although the method is new, already a number of noted music teachers are using it and reporting the same type of results as the teachers at Monarch.

The electronic memory system of music instruction promises to result in more and better musicians generally, and to stimulate the already important trend in the world of music, which is evidencing itself in the tremendous increase in the number of people who are learning to play various instruments. The chances are much better, with electronic memory, that a child who embarks on the study of music will stick with it until he attains at least moderate mastery of his instrument.

The need to *learn* to play—the taking of lessons—in order to enjoy a musical instrument always has been the greatest deterrent to the development of individual talent for musical performance. The easier it is to learn to play, and the more fun it is, the more people will be playing musical instruments for their own enjoyment.

Many teachers who have adopted it recognize the electronic memory system as a long step forward, for it enables the teacher to modernize a process that has changed very little through the centuries.

Although recording has been recognized generally for a long time as a valuable teaching technique, it has been limited until recently to occasional test recordings to check a student's progress. The electronic memory method of music instruction differs from that procedure in that it permits recording every lesson in its entirety.

Besides this ability to record every lesson without interruption, the wire recorder has the advantages of simplicity of recording and economy. Magnetic wire recording is the only type that has all of these features. It is simple to record a lesson, and after putting on the student's spool, both student and teacher forget the recorder. The wire recorder is moderately priced and inexpensive to operate, since the same wire can be used over and over, eliminating the need for constantly buying recording blanks. Upkeep is negligible and service, when needed, is uncomplicated and therefore low in cost. If the wire breaks, it is mended by tying a square knot. With the machine, one gets a 15-minute, a half-hour and a one-hour spool. With proper care, this is all a student needs for a year or more.

For studios and conservatories, a Webster-Chicago semi-portable or studio model wire recorder can be used. Students, as a rule, get the portable model.

THE INFLUENCE OF THE TEMPERATURE AND THE PERIOD OF KEEPING UPON THE BIOCHEMICAL CHANGES IN THE COMMON FOWL, *GALLUS DOMESTICUS*[1]

BY

JOSEPH SAMUEL HEPBURN[2]

Between the years 1905 and 1920, the Food Research Laboratory of the Bureau of Chemistry, United States Department of Agriculture, had its headquarters in Philadelphia. Its work appertained to biochemical and related changes in perishable animal foodstuffs, chiefly poultry, eggs, milk, fish, and shell fish, during their passage from the producer to the ultimate consumer. The author was associated with that laboratory during its Philadelphia period; his work was on milk, poultry, and eggs. The results of the study of biochemical and bacterial changes in milk and cream have been presented in a prior publication (1).[3]

The results of the work on shell eggs have also been published (2).

It is the purpose of this paper to present a resumé of extensive researches on the chemical changes in gross composition of the meat, changes in its nitrogen partition, changes in the constants of the fat of the adipose tissue, changes in the bacterial content of the flesh, and changes in the histology of the muscle of chickens during (1) various periods of cold storage in the frozen state at a temperature of −9.4 to −12.2° C.; (2) storage in a "chill room" at a temperature of 0.° C.; (3) keeping in an iced household refrigerator at a temperature of 7.2 to 12.8° C.; and (4) keeping at room temperature (average 23.9° C.).

While abstracts of these researches have appeared (3,4,5,6,25), complete summaries of the quantitative data have never been published.

The analytical procedures used in these studies have been described in preceding publications (7,8).

In this research the author participated in the chemical analyses, especially in the study of gross composition, and of fat constants. He was also responsible for a certain part of the histological work, and for the tabulation and interpretation of the bacteriological data. Participating in the laboratory work were E. Quintard St. John and Evelyn Witmer. The Chief of the Laboratory was M. E. Pennington. Consent to preparation and publication was graciously given by W. W. Skinner, Chief of the Bureau of Agricultural and Industrial Chemistry,

[1] Dissertation submitted to the Committee on Higher Degrees in Course of the Hahnemann Medical College and Hospital of Philadelphia, in partial fulfillment of the requirements for the Degree of Doctor of Chemistry, 1946.

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[3] The boldface numbers in parentheses refer to the references appended to this paper; see Part II to be published in this JOURNAL, June, 1950.

Agricultural Research Administration, United States Department of Agriculture.

Chickens were chosen as the basis of the research, since the poultry industry is of such enormous economic importance. Thus, in the United States, in the year 1945, the production of chickens, excluding commercial broilers, amounted to 731,079,000 birds, weighing 3,026,451,000 lb. and valued at $789,452,000. In the same year, the production of commercial broilers amounted to 312,200,000 birds, weighing 943,509,000 lb. and valued at $279,146,000. The cold storage holdings of "total poultry" during 1945 had a high value of 269,021,000 lb. on January 1, and a low value of 97,211,000 lb. on July 1 (9). Chickens on the farms of Pennsylvania on January 1, 1945 numbered 23,216,000, valued at $34,128,000 (24). Other reasons were the fact that chickens are readily obtained, highly organized animals; and their entire musculature may be used in the preparation of a sample for analysis since the carcass is relatively small. The chickens used were of three breeds, Plymouth Rock, Rhode Island Red, and Leghorn. They included squab broilers (dressed weight less than 1.25 lb.), broilers (dressed weight 1.25 to 2.5 lb.), and roasters (dressed weight 3.5 lb. and over). The two grades of broilers have been included in one group in the tabulation of results. All the chickens were well-bled, dry-picked (dry plucked) and chilled in dry air, for at least 24 hr. The procedure for killing and dressing the chickens has been described by Pennington and Betts (10). The birds destined for cold storage were wrapped individually in parchment paper, packed in wooden boxes, frozen solid in a mechanically refrigerated "sharp freezer" at a temperature of −14.4° C. for a period of at least 48 hr., and then kept in a mechanically refrigerated "freezer" at a temperature of −9.4° to −12.2° C. for periods as long as 16 or more months. Parallel studies were made with uneviscerated (undrawn) and completely eviscerated (drawn) birds.

The gross composition, of the meat, was obtained by actual determination of the percentages of total solids, ether extract (designated fat in previous papers), and ash, and by calculation of the percentages of water, protein and creatinine. The percentage of water was calculated by subtraction of the percentage of total solids from 100. The percentage of protein was calculated by subtraction of the percentage of amino acid and basic (meat base) nitrogen actually present in the meat from the percentage of total nitrogen actually present in the meat, and multiplication of the remainder by the factor 6.25. The creatinine was calculated by multiplication of the percentage of amino acid and basic nitrogen actually present in the meat by the factor 3.11. The sum of the percentages of water, ether extract, ash, protein, and creatinine was approximately 100. In a series of 136 analyses, the average value of this sum was 99.06 per cent; in 122 analyses it was above 97.5 per cent; the maximum value was 101.72 per cent, the minimum (an atypical) value 90.74 per cent, next to the minimum value 95.76 per cent.

In the determination of the nitrogen partition in the meat, the total nitrogen was determined on the meat itself. An aqueous extract was prepared from a sample (40 to 60 g.) of the meat, and analyzed quantitatively for its (1) total water-soluble nitrogen, (2) nitrogen coagulable by heat, (3) proteose (formerly termed albumose) nitrogen, (4) peptone nitrogen, and (5) amino acid and basic nitrogen. Each of these forms of nitrogen was calculated first as actual percentage of the meat, and then as percentage of the total nitrogen of the meat. For brevity, only the latter figures are here presented. The light meat and the dark meat were analyzed separately.

For study of the fat constants, the skin and its adherent adipose tissue and the adipose tissue from the abdominal cavity were ground in a meat chopper, and extracted for 72 hr. with petroleum ether U.S.P. in a Soxhlet apparatus. After complete removal of the solvent by distillation on a water bath, the residue was used for study of the fat constants. The iodine number was determined by the Hanus method. The index of refraction was measured at a temperature of 35° C.

FRESH CHICKENS

In gross composition the two breeds of broilers, Plymouth Rock and Leghorn, showed no marked differences. The Plymouth Rock broilers were slightly lower in water content of the musculature (on the average, by 1.15 per cent in the light meat and by 0.71 per cent in the dark meat), and slightly higher in its protein content (on the average, by 0.88 per cent in the light meat and by 1.20 per cent in the dark meat).

Upon comparison of the broilers as a whole and the roasters, with respect to their gross composition, the roasters contained a slightly lower percentage of water and a slightly higher percentage of protein; this was true of both the light meat and the dark meat. There were no noteworthy differences between roasters and broilers with respect to ether extract, ash, and creatinine.

Upon comparison of the light meat and the dark meat, with respect to their gross composition, the percentage of ether extract usually was higher and the percentage of protein lower in the dark meat than in the light meat; this was true of both roasters and broilers.

In the nitrogen partition in the musculature, the only noteworthy difference between the Plymouth Rock broilers and the Leghorn broilers was a consistently lower value for the total nitrogen of the aqueous extract in the Plymouth Rock birds.

The only noteworthy difference between the broilers and the roasters was the higher proteose nitrogen content of the broilers.

Upon comparison of the light meat and the dark meat, in both the roasters and the broilers, the light meat usually showed a higher value for the total nitrogen of the aqueous extract, the amino acid and basic nitrogen, and the peptone nitrogen, and a lower value for the proteose

nitrogen. The coagulable nitrogen of the aqueous extract tended to have a lower value in the light meat of broilers and a higher value in the light meat of roasters.

TABLE I.—*Fresh Chickens—Gross Composition.*
(*Percentage composition of the muscle*)

	Plymouth Rock Broilers 8 Samples 70 Birds	Leghorn Broilers 8 Samples 80 Birds	Broilers 16 Samples 150 Birds	Roasters 9 Analyses 17 Birds
Water				
Light Meat				
Minimum	73.32	74.05	73.32	73.30
Maximum	75.61	76.21	76.21	75.73
Average	74.60	75.15	74.88	74.14
Dark Meat				
Minimum	71.75	73.51	71.75	73.02
Maximum	75.91	76.04	76.04	75.86
Average	74.49	75.20	74.85	74.30
Ether Extract				
Light Meat				
Minimum	0.49	0.83	0.49	0.17
Maximum	1.96	2.04	2.04	1.97
Average	1.26	1.24	1.25	1.21
Dark Meat				
Minimum	2.40	2.97	2.40	1.38
Maximum	4.66	4.47	4.66	4.45
Average	3.42	3.50	3.46	3.19
Ash				
Light Meat				
Minimum	1.17	1.15	1.15	1.11
Maximum	1.40	1.27	1.40	1.33
Average	1.28	1.22	1.25	1.22
Dark Meat				
Minimum	1.16	1.08	1.08	1.12
Maximum	1.32	1.30	1.32	1.49
Average	1.23	1.19	1.21	1.24
Protein				
Light Meat				
Minimum	17.94	19.44	17.94	21.00
Maximum	23.46	21.66	23.46	23.50
Average	21.28	20.40	20.84	21.76
Dark Meat				
Minimum	18.86	18.00	18.00	18.69
Maximum	21.69	19.88	21.69	23.13
Average	19.87	18.67	19.27	20.15
Creatinine				
Light Meat				
Minimum	0.97	0.67	0.67	0.92
Maximum	1.38	1.12	1.38	1.48
Average	1.08	0.96	1.02	1.22
Dark Meat				
Minimum	0.72	0.69	0.69	0.64
Maximum	0.92	1.02	1.02	1.10
Average	0.82	0.82	0.82	0.90

The differences between the two breeds of broilers, as shown by the fat constants, were so slight as to lack significance.

The same comment may be made upon comparison of the broilers

and the roasters, if the acid value (and its related constant, the percentage of free fatty acid calculated as oleic) be excepted. The minimum acid value was 0.3 in the broilers and 0.4 in the roasters; the maximum

TABLE II.—*Nitrogen Partition in the Muscle.*
(*Nitrogen of each fraction calculated as percentage of the total nitrogen of the meat*)

Percentage of Total Nitrogen of Muscle	Plymouth Rock Broilers 8 Samples 70 Birds	Leghorn Broilers 8 Samples 80 Birds	Broilers 16 Samples 150 Birds	Roasters 10 Samples 20 Birds
Total N of Aqueous Extract				
Light Meat				
Minimum	19.48	21.90	19.48	22.65
Maximum	27.15	27.30	27.30	27.80
Average	23.94	24.66	24.30	25.17
Dark Meat				
Minimum	17.40	19.94	17.40	14.30
Maximum	24.45	24.50	24.50	20.20
Average	21.05	22.41	21.73	18.66
Coagulable N of Aqueous Extract				
Light Meat				
Minimum	6.76	7.52	6.76	9.11
Maximum	11.90	11.60	11.90	13.70
Average	10.01	10.00	10.01	11.01
Dark Meat				
Minimum	6.72	9.08	6.72	6.45
Maximum	15.35	12.85	15.35	9.34
Average	10.34	10.81	10.58	8.18
Proteose N				
Light Meat				
Minimum	0.407	0.728	0.407	0.350
Maximum	1.19	1.22	1.22	0.775
Average	0.767	0.936	0.852	0.520
Dark Meat				
Minimum	0.478	0.677	0.478	0.263
Maximum	1.72	1.56	1.72	0.793
Average	1.03	1.10	1.07	0.540
Amino Acid and Basic N				
Light Meat				
Minimum	8.23	6.30	6.30	7.90
Maximum	13.38	9.88	13.38	12.17
Average	9.23	8.45	8.84	10.28
Dark Meat				
Minimum	6.92	6.77	6.77	5.33
Maximum	8.95	9.24	9.24	10.11
Average	7.64	7.96	7.80	8.49
Peptone N				
Light Meat				
Minimum	0.634	3.95	0.634	1.78
Maximum	5.46	7.91	7.91	5.55
Average	3.93	5.27	4.60	3.36
Dark Meat				
Minimum	0.211	0.123	0.123	0.000
Maximum	3.03	3.77	3.77	2.84
Average	2.04	2.54	2.29	1.45

acid value was, respectively, 7.9 and 6.9 in the two breeds of broilers, and 1.5 in the roasters; the average acid value was, respectively, 2.1 and 2.3 in the two breeds of broilers, and 0.8 in the roasters. In other

TABLE III.—*Fat Constants.*

	Plymouth Rock Broilers 8 Samples 70 Birds	Leghorn Broilers 8 Samples 80 Birds	Broilers 16 Samples 150 Birds	Roasters 9 Samples 17 Birds
Iodine Number				
Minimum	60.0	54.0	54.0	58.6
Maximum	68.5	66.1	68.5	71.2
Average	64.9	60.1	62.5	63.3
Saponification Number				
Minimum	162.4	159.3	159.3	154.9
Maximum	182.2	179.0	182.2	190.2
Average	170.8	169.8	170.3	172.9
Acid Value				
Minimum	0.3	0.3	0.3	0.4
Maximum	7.9	6.9	7.9	1.5
Average	2.1	2.3	2.2	0.8
Ester Value				
Minimum	157.8	156.6	156.6	153.9
Maximum	181.7	178.7	181.7	189.4
Average	168.7	167.5	168.1	172.1
Percentage Free Acid as Oleic				
Minimum	0.15	0.15	0.15	0.20
Maximum	3.97	3.47	3.97	0.76
Average	1.06	1.18	1.12	0.42
Hehner Number				
Minimum	73.81	73.16	73.16	73.15
Maximum	86.80	83.79	86.80	88.70
Average	81.59	78.44	80.02	81.27
Index of Refraction				
Minimum	1.4521	1.4541	1.4521	1.4490
Maximum	1.4621	1.4611	1.4621	1.4608
Average	1.4588	1.4599	1.4594	1.4561

words, the fat of the broilers usually had a higher content of free fatty acids.

More complete analyses of the fat were made on three samples obtained from fat old hens (fowls), birds somewhat older than those used in the preceding experiments.

Sample No.	1	2	3
Iodine number	75.6	71.8	66.6
Saponification number	196.2	192.9	168.1
Acid value	0.8	0.5	0.5
Ester value	195.4	192.4	167.6
Hehner number	96.34	95.21	93.68
Percentage free acid calculated as oleic	0.40	0.25	0.25
Percentage total soluble acids as butyric	0.36	0.42	0.053
Acetyl value	7.4	8.6	8.0
Acetyl saponification number	200.6	202.8	201.1
Percentage unsaponifiable matter	2.47	1.12	—
Index of refraction	1.4609	1.4607	1.4647
Viscosity at 40° C. (angular degrees)	—	—	28.2
Optical rotatory power of 50% solution in benzene, 200 mm. tube (Saccharimeter degrees)			+0.5

The values obtained with fresh chickens were also used as fresh standards in the study of the biochemical changes occurring during cold storage.

FREEZER STORAGE

Each analysis in this series was made upon a single chicken. However, three samples were analyzed in each of the four groups (uneviscerated broilers, eviscerated broilers, uneviscerated roasters, and eviscerated roasters) at each of the four periods of storage. These three samples represented, respectively, the three breeds (Plymouth Rock, Rhode Island Red, and Leghorn); in the tabulations, the minimum, maximum, and average values have been given for each of these groups of three birds. The analyses were made after storage for periods of 4, 8, 12, and 16 months.

TABLE IV.—*Chickens, Stored, Hard, Frozen—Gross Composition.*
(Percentage composition of the muscle)

	Period of Cold Storage, Months	Broilers		Roasters	
		Uneviscerated	Eviscerated	Uneviscerated	Eviscerated
Water					
Light Meat	4				
Minimum		74.16	72.61	73.82	73.78
Maximum		74.70	75.43	74.79	75.18
Average		74.46	73.71	74.15	74.70
Dark Meat	4				
Minimum		73.98	73.84	74.65	74.78
Maximum		74.56	75.90	76.48	76.32
Average		74.33	74.63	75.32	75.72
Light Meat	8				
Minimum		67.80	65.20	71.97	72.84
Maximum		71.37	69.68	73.72	74.00
Average		69.77	67.99	72.86	73.23
Dark Meat	8				
Minimum		70.28	67.10	72.22	72.34
Maximum		70.96	70.38	75.48	74.24
Average		70.73	68.43	73.74	73.04
Light Meat	12				
Minimum		67.88	60.64	67.71	70.82
Maximum		70.68	69.34	71.93	71.88
Average		69.66	64.71	69.84	71.35
Dark Meat	12				
Minimum		69.56	62.31	70.98	69.91
Maximum		69.84	70.16	72.34	75.18
Average		69.69	66.52	71.61	72.52
Light Meat	16				
Minimum		59.46	51.88	68.62	70.08
Maximum		70.01	68.74	70.32	71.35
Average		63.71	59.93	69.71	70.52
Dark Meat	16				
Minimum		63.90	64.78	69.64	68.97
Maximum		70.97	68.74	70.66	71.80
Average		67.09	66.27	69.99	70.05
Ether Extract					
Light Meat	4				
Minimum		0.18	0.16	0.15	0.24
Maximum		0.33	0.48	0.22	0.59
Average		0.28	0.30	0.19	0.36

TABLE IV.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Ether Extract (cont.)					
Dark Meat	4				
Minimum		1.84	1.48	1.53	1.58
Maximum		2.28	1.77	2.20	2.87
Average		2.02	1.59	1.88	2.02
Light Meat	8				
Minimum		0.52	0.21	0.33	0.28
Maximum		1.06	1.25	0.70	0.88
Average		0.75	0.77	0.53	0.50
Dark Meat	8				
Minimum		1.20	1.22	1.15	1.88
Maximum		2.78	2.85	2.48	3.20
Average		2.23	2.29	2.01	2.33
Light Meat	12				
Minimum		0.87	1.38	1.09	0.61
Maximum		1.77	3.25	1.42	2.56
Average		1.33	2.07	1.28	1.64
Dark Meat	12				
Minimum		2.36	2.90	2.23	1.48
Maximum		4.02	5.71	3.21	4.38
Average		3.23	4.09	2.76	3.39
Light Meat	16				
Minimum		1.22	1.33	0.56	0.80
Maximum		2.29	3.59	1.58	1.73
Average		1.66	2.21	1.00	1.34
Dark Meat	16				
Minimum		3.37	3.65	1.88	2.89
Maximum		6.26	3.86	3.96	4.45
Average		4.39	3.79	2.95	3.61
Ash					
Light Meat	4				
Minimum		1.12	1.16	1.17	1.15
Maximum		1.23	1.32	1.24	1.20
Average		1.19	1.21	1.19	1.18
Dark Meat	4				
Minimum		1.18	1.18	1.17	1.12
Maximum		1.29	1.26	1.20	1.18
Average		1.24	1.23	1.18	1.15
Light Meat	8				
Minimum		1.27	1.33	1.20	1.16
Maximum		1.45	2.13	1.25	1.40
Average		1.35	1.69	1.22	1.25
Dark Meat	8				
Minimum		1.31	1.22	1.14	1.14
Maximum		1.68	1.58	1.29	1.17
Average		1.46	1.40	1.21	1.16
Light Meat	12				
Minimum		1.23	1.22	1.24	1.16
Maximum		1.31	1.65	1.34	2.10
Average		1.27	1.50	1.30	1.55
Dark Meat	12				
Minimum		1.26	1.32	1.23	1.18
Maximum		1.32	2.02	1.97	1.23
Average		1.30	1.67	1.49	1.20
Light Meat	16				
Minimum		1.34	1.38	1.24	1.17
Maximum		1.67	2.76	1.27	1.37
Average		1.54	1.97	1.26	1.25
Dark Meat	16				
Minimum		1.24	1.28	1.26	1.20
Maximum		1.45	1.88	1.39	1.68
Average		1.33	1.57	1.31	1.42

TABLE IV.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Protein					
Light Meat	4				
Minimum		22.75	21.69	22.31	21.44
Maximum		23.69	24.25	22.75	21.94
Average		23.17	23.02	22.58	21.71
Dark Meat	4				
Minimum		20.80	21.80	20.00	19.70
Maximum		22.50	22.25	20.80	20.45
Average		21.75	22.08	20.42	20.17
Light Meat	8				
Minimum		23.92	24.30	22.32	22.11
Maximum		25.31	26.41	23.23	23.15
Average		24.82	25.14	22.65	22.75
Dark Meat	8				
Minimum		22.47	22.77	20.31	20.95
Maximum		24.12	25.85	22.34	22.73
Average		23.12	24.44	21.08	21.79
Light Meat	12				
Minimum		22.30	25.35	23.26	22.81
Maximum		25.14	29.91	25.02	23.70
Average		23.57	28.29	24.24	23.32
Dark Meat	12				
Minimum		21.85	24.17	21.04	20.14
Maximum		23.32	25.17	23.19	21.92
Average		22.69	24.71	22.44	20.79
Light Meat	16				
Minimum		25.38	27.13	23.96	23.69
Maximum		32.19	34.55	24.85	24.54
Average		28.98	30.39	24.33	24.12
Dark Meat	16				
Minimum		23.65	24.18	23.31	22.52
Maximum		26.54	28.04	23.97	24.30
Average		25.00	26.63	23.60	23.23
Creatinine					
Light Meat	4				
Minimum		1.01	1.06	1.09	0.998
Maximum		1.15	1.13	1.19	1.18
Average		1.09	1.09	1.12	1.08
Dark Meat	4				
Minimum		0.818	0.676	0.811	0.796
Maximum		0.872	0.893	0.910	0.809
Average		0.84	0.76	0.87	0.80
Light Meat	8				
Minimum		1.18	1.22	1.29	1.31
Maximum		1.41	1.48	1.38	1.42
Average		1.26	1.38	1.35	1.38
Dark Meat	8				
Minimum		0.977	1.00	0.883	1.02
Maximum		1.03	1.26	1.08	1.07
Average		1.00	1.13	0.986	1.04
Light Meat	12				
Minimum		1.67	1.82	1.36	1.45
Maximum		1.91	2.12	1.63	1.67
Average		1.75	1.93	1.47	1.59
Dark Meat	12				
Minimum		1.22	1.15	0.902	1.05
Maximum		1.44	1.28	1.16	1.22
Average		1.35	1.24	1.06	1.13
Light Meat	16				
Minimum		1.71	1.74	1.76	1.70
Maximum		2.27	3.03	1.94	1.94
Average		1.98	2.29	1.83	1.79
Dark Meat	16				
Minimum		1.17	1.19	1.28	1.19
Maximum		1.53	1.45	1.39	1.30
Average		1.33	1.33	1.34	1.24

During cold storage in the mechanically refrigerated freezer, the most striking change in gross chemical composition was the decrease in the water content of the musculature. This decrease occurred in both the light meat and the dark meat, of both roasters and broilers, whether uneviscerated or eviscerated, and tended markedly to be progressively greater, as the period of storage lengthened. The average values always showed the lowest percentage of water, and, therefore, the greatest loss of that compound, in the samples stored for 16 months. The minimum values and the maximum values, with a few exceptions, exhibited the same general tendency. Under the same conditions, the loss of water usually was greater in the light meat than in the dark meat, and almost invariably was greater in broilers than in roasters. No uniform trend distinguished uneviscerated from eviscerated birds.

As a result of this desiccation, the percentage of total solids and of their constituents (ether extract, ash, protein, and creatinine) increased during cold storage hard frozen.

TABLE V.—*Nitrogen Partition in the Muscle.*
(*Nitrogen of each fraction calculated as percentage of the total nitrogen of the meat*)

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Total N of Aqueous Extract					
Light Meat	4				
Minimum		22.60	20.09	24.40	25.30
Maximum		24.28	28.30	27.90	26.10
Average		23.23	23.87	26.16	25.73
Dark Meat	4				
Minimum		18.50	17.35	21.10	20.60
Maximum		22.20	20.15	22.00	21.60
Average		20.53	19.15	21.44	21.20
Light Meat	8				
Minimum		22.05	22.15	24.76	23.75
Maximum		26.80	22.75	25.96	25.51
Average		24.38	23.36	25.49	24.85
Dark Meat	8				
Minimum		19.35	18.71	20.15	19.67
Maximum		23.50	22.10	21.90	24.75
Average		21.47	20.23	21.07	21.82
Light Meat	12				
Minimum		22.59	21.62	21.50	22.52
Maximum		26.08	21.90	22.90	23.08
Average		24.28	21.81	22.10	22.80
Dark Meat	12				
Minimum		20.13	18.55	17.18	18.70
Maximum		22.53	21.66	19.60	21.26
Average		21.38	19.59	18.01	19.92
Light Meat	16				
Minimum		21.80	21.31	21.97	23.96
Maximum		23.47	27.12	24.43	25.43
Average		22.52	23.31	23.52	24.69
Dark Meat	16				
Minimum		17.84	17.54	17.40	19.35
Maximum		22.32	18.34	20.02	20.99
Average		19.62	17.82	18.93	19.98

TABLE V.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis- cerated	Evis- cerated	Unevis- cerated	Evis- cerated
Coagulable N of Aqueous Extract					
Light Meat	4				
Minimum		8.70	8.00	10.90	11.20
Maximum		11.88	12.60	12.60	11.85
Average		9.78	9.95	11.66	11.44
Dark Meat	4				
Minimum		7.60	7.05	10.28	9.91
Maximum		11.50	10.70	11.03	10.54
Average		9.52	8.99	10.48	10.17
Light Meat	8				
Minimum		9.17	7.22	9.58	9.28
Maximum		11.55	10.37	10.92	10.38
Average		10.51	8.46	10.36	9.84
Dark Meat	8				
Minimum		5.36	7.59	8.44	7.56
Maximum		9.92	12.15	9.80	12.52
Average		8.17	9.43	9.25	9.89
Light Meat	12				
Minimum		7.68	6.87	7.92	8.65
Maximum		9.41	7.82	8.49	9.31
Average		8.73	7.20	8.22	9.08
Dark Meat	12				
Minimum		7.07	7.42	6.57	8.23
Maximum		9.90	9.42	8.45	9.49
Average		8.71	8.22	7.63	8.75
Light Meat	16				
Minimum		7.60	8.16	7.89	9.76
Maximum		9.07	8.74	9.84	10.75
Average		8.20	8.54	8.78	10.14
Dark Meat	16				
Minimum		7.21	6.44	6.75	8.33
Maximum		9.81	7.79	8.12	8.86
Average		8.25	6.95	7.55	8.63
Proteose N					
Light Meat	4				
Minimum		0.565	0.570	0.650	0.742
Maximum		0.848	0.953	0.710	0.951
Average		0.700	0.700	0.680	0.850
Dark Meat	4				
Minimum		0.946	0.809	0.654	0.793
Maximum		1.100	1.000	1.070	1.360
Average		1.030	0.930	0.910	1.080
Light Meat	8				
Minimum		0.730	0.315	0.275	0.411
Maximum		0.790	0.467	0.474	0.707
Average		0.750	0.380	0.402	0.560
Dark Meat	8				
Minimum		1.05	0.574	0.560	0.736
Maximum		1.76	0.638	0.922	0.897
Average		1.30	0.610	0.700	0.840
Light Meat	12				
Minimum		0.375	0.150	0.161	0.235
Maximum		0.420	0.366	0.382	0.335
Average		0.390	0.230	0.250	0.299
Dark Meat	12				
Minimum		0.580	0.380	0.425	0.443
Maximum		1.060	0.490	0.617	0.974
Average		0.860	0.440	0.510	0.620

TABLE V.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Proteose N (cont.)					
Light Meat	16				
Minimum		0.356	0.429	0.348	0.352
Maximum		0.629	0.545	0.568	0.475
Average		0.470	0.500	0.430	0.410
Dark Meat	16				
Minimum		0.457	0.549	0.468	0.678
Maximum		0.970	0.818	0.570	1.040
Average		0.650	0.720	0.500	0.805
Amino Acid and Basic N					
Light Meat	4				
Minimum		8.15	8.15	8.85	8.55
Maximum		9.10	9.47	9.57	9.77
Average		8.65	8.73	9.35	9.11
Dark Meat	4				
Minimum		7.15	5.76	7.55	7.25
Maximum		7.32	7.52	8.12	7.53
Average		7.23	6.45	7.92	7.39
Light Meat	8				
Minimum		8.59	9.16	10.38	10.65
Maximum		10.05	10.73	10.95	10.96
Average		9.32	9.94	10.67	10.83
Dark Meat	8				
Minimum		7.57	7.55	7.93	8.63
Maximum		8.36	9.15	8.96	8.94
Average		7.99	8.55	8.57	8.74
Light Meat	12				
Minimum		11.77	11.00	10.09	10.99
Maximum		14.67	12.60	11.61	12.68
Average		13.01	12.04	10.89	12.08
Dark Meat	12				
Minimum		9.72	8.77	7.25	9.49
Maximum		11.74	9.40	10.00	10.08
Average		10.72	9.16	8.68	9.85
Light Meat	16				
Minimum		11.86	10.84	12.85	12.63
Maximum		12.43	17.12	13.57	13.71
Average		12.11	13.13	13.10	13.00
Dark Meat	16				
Minimum		9.04	8.80	9.90	9.16
Maximum		10.40	9.53	10.59	10.37
Average		9.66	9.10	10.23	9.68
Peptone N					
Light Meat	4				
Minimum		3.74	3.65	3.85	3.49
Maximum		4.92	5.15	4.95	4.79
Average		4.19	4.46	4.50	4.35
Dark Meat	4				
Minimum		2.36	1.85	1.74	2.36
Maximum		3.17	3.84	2.41	2.84
Average		2.64	2.81	2.17	2.55
Light Meat	8				
Minimum		1.82	4.09	3.77	2.95
Maximum		5.18	5.23	4.25	4.14
Average		3.76	4.60	4.06	3.62
Dark Meat	8				
Minimum		3.19	0.32	2.24	2.08
Maximum		5.05	2.94	2.79	2.49
Average		3.90	1.67	2.54	2.32

TABLE V.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Peptone N (cont.)					
Light Meat	12				
Minimum		1.78	1.96	1.77	0.478
Maximum		2.72	2.90	3.40	2.58
Average		2.15	2.30	2.75	1.34
Dark Meat	12				
Minimum		0.62	1.63	0.615	0.055
Maximum		1.84	2.44	1.62	1.32
Average		1.06	2.04	1.17	0.70
Light Meat	16				
Minimum		1.67	0.83	0.85	0.86
Maximum		1.84	1.47	1.67	1.56
Average		1.78	1.16	1.22	1.13
Dark Meat	16				
Minimum		0.91	0.21	none	0.22
Maximum		1.14	1.75	1.26	1.58
Average		1.06	1.05	0.67	0.88

Scrutiny of the nitrogen partitions reveals proteolysis with the production of amino acids, especially during the last half of the storage period. The average values for amino acid and basic nitrogen, as

TABLE VI.—*Fat Constants.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Iodine Number	4				
Minimum		49.6	49.2	49.1	44.3
Maximum		64.4	60.8	65.1	53.7
Average		55.3	54.2	57.4	49.8
	8				
Minimum		48.6	52.3	71.2	62.5
Maximum		74.4	62.8	77.7	71.0
Average		60.5	58.9	73.5	67.0
	12				
Minimum		66.6	59.2	54.8	65.0
Maximum		68.3	66.8	74.1	72.4
Average		67.7	64.0	66.3	68.9
	16				
Minimum		68.8	52.3	65.6	70.4
Maximum		73.8	73.0	72.4	71.4
Average		70.8	63.4	69.9	71.0
Saponification Number	4				
Minimum		122.7	137.5	133.3	109.6
Maximum		198.2	199.5	167.0	132.0
Average		156.8	161.7	145.2	123.9
	8				
Minimum		149.0	163.3	161.8	170.7
Maximum		181.2	173.0	180.5	173.8
Average		165.1	168.2	172.0	172.3
	12				
Minimum		151.1	159.6	145.4	164.1
Maximum		188.3	186.4	185.1	191.5
Average		166.3	177.1	169.6	179.0
	16				
Minimum		173.9	158.6	191.9	182.8
Maximum		196.1	189.0	196.9	193.8
Average		184.7	177.2	194.9	189.8

TABLE VI.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Acid Value	4				
Minimum		2.2	0.9	0.3	1.0
Maximum		2.9	3.1	8.8	1.5
Average		2.5	1.8	4.4	1.3
	8				
Minimum		1.1	1.5	0.6	0.4
Maximum		8.4	3.2	0.9	4.8
Average		3.9	2.4	0.8	2.0
	12				
Minimum		2.4	1.6	1.1	0.4
Maximum		5.2	4.6	2.3	4.5
Average		3.5	2.8	1.5	2.4
	16				
Minimum		4.8	4.4	3.1	3.8
Maximum		6.4	5.0	11.8	6.4
Average		5.4	4.7	6.7	4.7
Ester Value	4				
Minimum		120.2	136.6	124.5	108.1
Maximum		195.3	196.4	163.1	130.6
Average		154.3	159.9	140.8	122.6
	8				
Minimum		146.8	160.1	160.9	169.8
Maximum		180.1	171.5	179.7	173.4
Average		163.5	165.8	171.2	171.6
	12				
Minimum		148.7	158.0	143.1	163.7
Maximum		185.4	183.3	184.0	189.3
Average		162.8	174.3	168.1	176.6
	16				
Minimum		167.5	153.8	180.1	179.0
Maximum		191.3	184.0	193.8	189.8
Average		179.3	172.5	188.2	185.1
Percentage Free Acid as Oleic	4				
Minimum		1.11	0.43	0.23	0.50
Maximum		1.46	1.56	4.42	0.75
Average		1.28	0.90	2.21	0.65
	8				
Minimum		0.55	0.75	0.30	0.20
Maximum		4.23	1.61	0.45	2.41
Average		1.96	1.18	0.38	1.02
	12				
Minimum		1.19	0.80	0.55	0.20
Maximum		2.62	2.31	1.16	2.26
Average		1.76	1.38	0.77	1.19
	16				
Minimum		2.41	2.21	1.56	1.90
Maximum		3.22	2.52	5.94	3.22
Average		2.70	2.38	3.37	2.38
Hehner Number	4				
Minimum		54.75	61.97	62.47	49.94
Maximum		90.58	67.98	75.72	62.22
Average		70.53	64.98	69.20	57.15

TABLE VI.—*Continued.*

	Period of Cold Storage, Months	Broilers		Roasters	
		Unevis-cerated	Evis-cerated	Unevis-cerated	Evis-cerated
Hehner Number (cont.)	8				
Minimum		70.60	79.90	78.00	81.20
Maximum		83.20	79.90	84.53	82.80
Average		76.90	79.90	81.59	82.00
	12				
Minimum		69.59	75.10	68.56	79.48
Maximum		90.80	88.58	89.23	90.93
Average		79.52	81.84	80.90	85.10
	16				
Minimum		80.35	86.08	90.85	86.15
Maximum		94.30	90.00	92.49	91.70
Average		87.11	88.04	91.67	89.82
Index of Refraction	4				
Minimum		1.4567	1.4536	1.4584	1.4395
Maximum		1.4613	1.4549	1.4624	1.4560
Average		1.4590	1.4543	1.4608	1.4468
	8				
Minimum		1.4610	1.4622	1.4624	1.4630
Maximum		1.4621	1.4660	1.4687	1.4652
Average		1.4616	1.4639	1.4648	1.4641
	12				
Minimum		1.4624	1.4613	1.4624	1.4612
Maximum		1.4660	1.4637	1.4652	1.4674
Average		1.4637	1.4627	1.4642	1.4641
	16				
Minimum		1.4621	1.4626	1.4607	1.4611
Maximum		1.4644	1.4644	1.4631	1.4635
Average		1.4632	1.4637	1.4621	1.4624

percentage of the total nitrogen of the meat, were: in *fresh broilers*, light meat 8.84, dark meat 7.80; in *fresh roasters*, light meat 10.28, dark meat 8.49. During *cold storage* hard frozen for periods of 4, 8, 12, and 16 months, respectively, the values were: in *uneviscerated broilers*, light meat 8.65, 9.32, 13.01, 12.11, dark meat 7.23, 7.99, 10.72, 9.66; in *eviscerated broilers*, light meat 8.73, 9.94, 12.04, 13.13, dark meat 6.45, 8.55, 9.16, 9.10; in *uneviscerated roasters*, light meat 9.35, 10.67, 10.89, 13.10, dark meat 7.92, 8.57, 8.68, 10.23; in *eviscerated roasters*, light meat 9.11, 10.83, 12.08, 13.00, dark meat 7.39, 8.74, 9.85, 9.68. A definite tendency existed for this fraction of the nitrogen to increase as the period of storage lengthened. This increase in amino acid and basic nitrogen was primarily at the expense of the proteose nitrogen and the peptone nitrogen which showed a marked tendency to decrease.

Certain of the fat constants changed during storage. Thus the iodine number decreased uniformly during the first four months of storage hard frozen, then uniformly tended to increase; this was especially true of the average values.

The saponification number and the Hehner number exhibited a marked tendency to change in the same direction at the same time. Thus, in the average values, both constants decreased uniformly at four months storage and increased uniformly at 16 months storage.

The acid value tended markedly to increase during storage, usually in a progressive manner.

New Building Construction Technique.—The new Conair process of construction for everything from small homes to large super-structural buildings, (described on p. 262 of the March JOURNAL), was approved recently by the Los Angeles Building Commission. This approval by the Commission now paves the way for Conair Sales, Inc. to release their national program for licensing contractors to use their exclusive process for building these all-steel reinforced concrete units.

This enables the individual contractor to offer the public a lifetime home, school, or all-purpose building at a cost of less than five dollars per square foot.

All this is made possible by the invention of the Conair gun which pneumatically projects liquid cement, mixed with insulation, water-proofing and other essential ingredients against steelforms and the sensational new Fiberglas balloon roof.

This new device results in a structure which can be put up in twelve hours and which can be converted into every channel of construction purpose, whether it be for the individual home or for large industrial purposes.

The first of these is being built in Van Nuys, California, and will be used as a model for contractors and building trades men who have long had their eye on this unusual development, one of the unique developments in the past century of homebuilding.

The manner in which the first Conair structure is being built is through the following procedure, which would be impossible without the exclusive use of the fantastic Conair gun. The step by step method, after placing conventional type concrete footings to meet local code requirements, is to place ½-in. steel reinforcing bars 8-in. deep in footing on 36-in. centers and to a height of 8 ft. at top. After roughing in plumbing, the outside wall forms are secured on footings and bolted securely together. The window and door frames can be placed in any desired position against the inside of steel forms by hanging wires from top of forms without altering original architectural plan. Wire mesh is then placed on all forms and tied to vertical ½-in. bars so that it will be held in center of 4-in. wall. Window and door frames are tied to mesh. The electric conduit is then placed in the usual manner. From the inside, the cement is projected through the Conair gun against all outside forms to a thickness of 4 in. and to a height of 8 ft. Wall partitions are made in the same manner but to a thickness of 3 in. The Fiberglas balloon is secured to outer edge of steel forms and after inflating the balloon, the same gun process is utilized projecting cement from outside against Fiberglas balloon. This is all sprayed with special moisture-proof paint. Interior walls may be papered, painted or paneled.

This final process makes the Conair building fire, earthquake and vermin proof, and eliminates most maintenance costs.

Detailed information regarding this new building development can be obtained from the offices of Conair Sales, Inc., 12147 Riverside Drive, North Hollywood, Calif.

Grease solvents may be easily reclaimed by filtering the used liquid through an ordinary automobile oil-filter element, according to a mechanic who tried the method at the Barstow (Calif.) Marine Corps Depot of Supplies. Two containers, in the form of old oil cans, were rigged one above the other, with a salvaged filter element between the two, fitted over a ¼-inch pipe at the bottom of the upper can. Straight savings are realized, since all parts are from salvage ordinarily found in garages.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS*

FIRE-RETARDANT COATINGS FOR AIRCRAFT

As a result of a joint research program between the National Bureau of Standards and the Civil Aeronautics Administration, coatings have been developed for fabric-covered aircraft which approximately double the time interval between ignition of the fabric and its destruction by fire. These findings, based on both laboratory and wind-tunnel burning tests, provide a basis for more effective extinguishment of fires in flight, particularly those arising from power plants in small craft.

No fire-retardant film-forming materials are known which tauten airplane fabrics as effectively and as permanently as do the dopes based on the cellulose derivatives. These dopes, however, are highly inflammable, and the addition of fire-retardant substances lessens their capacity to tauten. Efforts were therefore directed toward the development of highly efficient fire-retardant coatings to be applied to the surface after it is already doped. In designing the coatings, the requirements of aircraft use made it necessary to consider also aerodynamic smoothness, adhesion, flexibility, and other features.

Fifteen of the more promising coating systems were selected for full-scale wind-tunnel tests. Test panels, 12 inches square, prepared by applying from one to four coats of fire-retardant lacquer to fabric doped with the usual six coats of cellulose acetate butyrate, were placed in the center of the lower surface of a steel wing suspended in a 70-mile-per-hour air stream. A spray gun then introduced a uniform spray of aviation gasoline into the air stream, and the spray was ignited by a spark from an air-craft spark plug. This enveloped the wing section in burning gasoline, insuring continuous contact of the specimen with flame during the entire test. The time for destruction of the outer coating and the time of fabric failure were noted, while temperatures were recorded by means of thermocouples and rapid-response recording pyrometers.

The evidence presented by the wind-tunnel tests showed clearly that it is possible to increase the time for fabric destruction from the six seconds characteristic of cellulose acetate butyrate to about 12 seconds. Although fire-retardancy is increased for higher pigment contents, such over-pigmented coatings are not sufficiently durable. Some additional improvement can be achieved by designing the outer coating to have greater mechanical strength after burning so that it will not be blown away so easily by the wind stream.

* Communicated by the Director.

PROPERTIES OF LIGHTWEIGHT AGGREGATE CONCRETES

A study of eleven lightweight concrete aggregates carried out at the National Bureau of Standards has shown that it is possible to make concretes of low cement content with excellent workability, sufficient strength, and adequate heat insulation for certain applications in building construction. The aggregates consisted of exfoliated vermiculite, sintered diatomite, sintered fly ash, expanded perlite, shale, slate, clay, three expanded slags, and one natural material, pumice.

The investigation consisted of two parts: (1) Properties of the aggregates themselves and (2) properties of concrete containing various proportions of cement and aggregates. The proportions of cement to aggregate were such as to produce concrete mixtures from each aggregate containing nominally three, five, seven, and nine bags of cement per cubic yard of concrete. The consistency of each batch of concrete was measured by means of the standard slump test.

It was found that concretes, weighing as little as one-fifth the weight of ordinary concrete, are possible by using lightweight aggregates. Though these extreme lightweight concretes developed little strength, thermal conductivities as low as one-tenth that of sand-gravel concrete were exhibited. Other lightweight aggregate concretes developed compressive strengths between 1000 and 7000 pounds per square inch, and weighed appproximately one-third to two-thirds as much as sand-gravel concrete. Their thermal conductivities when dry were of the order of one-fourth to one-half those of the ordinary dense concrete. Most lightweight aggregates had relatively high water absorption, and shrinkage of the concretes made with them was approximately two or more times that of dense aggregate concrete. Except for lean 3-bag mixes, lightweight concrete containing air-entraining agents, in general, exhibited remarkable resistance to laboratory freezing and thawing tests of a rather severe nature.

NATURE OF ADHESION

In recent years the nature of adhesion has become the subject of a fundamental research program at the National Bureau of Standards. This project, sponsored by various Government agencies, was initiated in 1945 with a survey of the literature on adhesives and the theory of adhesion, and was extended to include investigations of the adhesive properties of a wide variety of adhesives and adherends.

Among the adhesives included in the Bureau's investigation were cellulose nitrate, polyvinyl acetate, resorcinol-formaldehyde, casein, gum arabic, natural rubber, and neoprene. These were modified as little as possible, so that the relation between adhesive and adherend would be in the simplest possible combination. The adherends chosen, aluminum alloy, stainless steel, paper phenolic laminate, plate glass, birch wood,

and hard rubber, are a fair sampling of the materials of industry. They have a wide range of elastic moduli, the property best correlated with bond shear strength, and their chemical and physical structure make possible a variety of adhesive bonds.

All combinations were subjected to shear and tensile tests. In addition, an impact test provided a means for studying differences between a brittle and a rubbery bond, and the fatigue test was utilized to investigate how a thermosetting and thermoplastic bond differs.

An evaluation of the data gathered in this project was obtained by tabulating the results with respect to two fundamental properties of the materials involved. These are dielectric constant and modulus of elasticity, the former an electrical and the latter a mechanical property. The dielectric constant was included because most modern theories attempt to explain adhesion on the basis of electrical forces. Greater correlation was noted with the moduli of elasticity than with the dielectric constants. When a high-modulus adhesive was used with a high-modulus adherend, the bond strength was negligible. When a low-modulus material was used, its strength became the limiting factor in the strength of the bonded assembly. The best results were obtained when medium-modulus materials were used with each other or with high-modulus materials.

Results of these investigations indicate that there are many variables involved in adhesion and that the breaking stress of a specimen is not always a measure of the adhesive-adherend bond strength. Instead it may be a measure of the cohesive strength of the adhesive or the adherend.

For a more thorough study of adhesion, it is necessary to separate the variables, whether electrical or mechanical, and to study each one separately. The program at the Bureau is being planned with this in mind. At present a study of the heats of wetting properties is under way in an effort to evaluate the importance of various polar groups.

HIGH-STRENGTH CERAMICS FOR HIGH-TEMPERATURE USE

Revolutionary developments in both the design and efficiency of jet-engine and gas-turbine power plants have emphasized the need for ceramics of great strength and durability at very high temperatures. These ceramics are used in place of metals or metal alloys because no metallic alloy known can withstand the extreme heat and strain encountered in these power plants without deforming.

Leading ceramic manufacturers were requested to submit specimens to the National Bureau of Standards for preliminary tests of bending at elevated temperatures and of resistance to thermal shock. Some materials developed previously at the Bureau were also tested. The bending-strength and thermal-shock tests showed the Bureau's products to be

superior to the commercial ones. A comprehensive investigation was then begun on six of the Bureau's oxide ceramic bodies to determine high-temperature strength and creep.

One method of testing consisted of heating the specimen and applying stress loads of 100 lbs. per square inch at weekly intervals until rupture, while observing changes in length. In another test the specimen was held at constant stress and temperature until failure in order to obtain comparisons with metal alloy tests. Strength and creep resistance decreased rapidly when temperatures were raised above 1900° F.

Data obtained from the tests reveal that some of the NBS oxide compositions are capable of withstanding high-temperature conditions far better than any other material now in use. An experimental gas turbine using blades fabricated from the oxide body of best proven characteristics is now in successful operation.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, APRIL 19, 1950

The Stated Monthly Meeting of The Franklin Institute was held on Wednesday evening, April 19, 1950, in the Lecture Hall. There were approximately 325 people in attendance.

The President called the meeting to order at 8:15 P.M. and requested approval of the minutes of the stated Institute meeting for February which had been printed in full in the March issue of the JOURNAL. The minutes were approved as printed.

The report of the Membership Department was presented as follows:

Sustaining	2
Active	37
Associate	26
Student	10

The total membership as of March 31 was reported to be 5927.

"Rocket to Mars," the Planetarium show scheduled to be shown through April and May, was announced by the President. He suggested that all avail themselves of the opportunity to see this unique presentation.

Dr. Richard C. Hitchcock, Research Engineer of the Westinghouse Electric Corporation, was the speaker of the evening and was introduced by Mr. Nalle.

"March of Research" was the topic of Dr. Hitchcock's talk. He gave a colorful lecture-demonstration of developments in research which are influencing the world today. He demonstrated many theories, including photoelasticity and magnetism, and their applications to industry. His talk proved educational and most entertaining.

HENRY B. ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, April 12, 1950.)

HALL OF THE COMMITTEE,
PHILADELPHIA, APRIL 12, 1950.

MR. LEWIS P. TABOR in the Chair.

The following reports were presented for final action:

No. 3204: Work of B. F. J. Schonland.

This report recommended the award of an Elliott Cresson Medal to Basil F. J. Schonland, of Johannesburg, South Africa, "In consideration of his extended work in the field of Atmospheric Electricity and of his experimental investigations into Lightning, and of his conclusions regarding the mechanism of the Lightning Discharge as it occurs in nature."

No. 3219: Newcomen Medal.

This report recommended the award of the Newcomen Medal to Isaac Harter, of Akron, Ohio, "In consideration of his diligent perseverance and continued interest in establishing the conditions governing the proper design of high pressure boilers and of his successful and accepted contributions to this field."

JOHN FRAZER,
Secretary to Committee.

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS

April 19, 1950

ACTIVE FAMILY

Edward I. Gallagher	Frank S. Loescher, Ph.D.	Col. Clayton E. Mullins, U.S.A. (Ret.)
William L. Hartley	Alexander Mackie, D.D.	Harry S. Nagin
Jacob Krause, M.D.		Charles R. Thomas, Jr.

ACTIVE

R. W. Bell	Edward G. Howe	Jesse T. Nicholson, M.D.
Charles McGhee Cowan	Horace C. Jenkins	George W. Patterson
John H. Dittmar	L. B. Jones	W. F. Rhinehart
Russell J. Down	Richard Ridgway Kennedy	George H. Roth
Joseph W. Gardiner, Jr.	Walter E. Krause	Richard Spurgeon
Benjamin F. Griffith, Jr.	Harold B. Leidy	Leland E. Wells
George J. Grinberg	Robert C. Medl, Jr.	Kenneth A. Whitecar

ACTIVE NON-RESIDENT

Anthony de V. Hitzenhammer	Will H. Rowand	Leslie S. Wilcoxson
	George L. Simpson	Harry E. Zankey

NECROLOGY

A. E. Gibbs '13	J. S. C. Harvey '37	Grace P. Richardson '38
H. M. Kaufmann '95	Charles S. Lee '39	Samuel Shoemaker '97
Alexander Klemin '35	Christian R. Lindback '36	Louis J. Warbeck '49

GOLDEN ANNIVERSARY DINNER

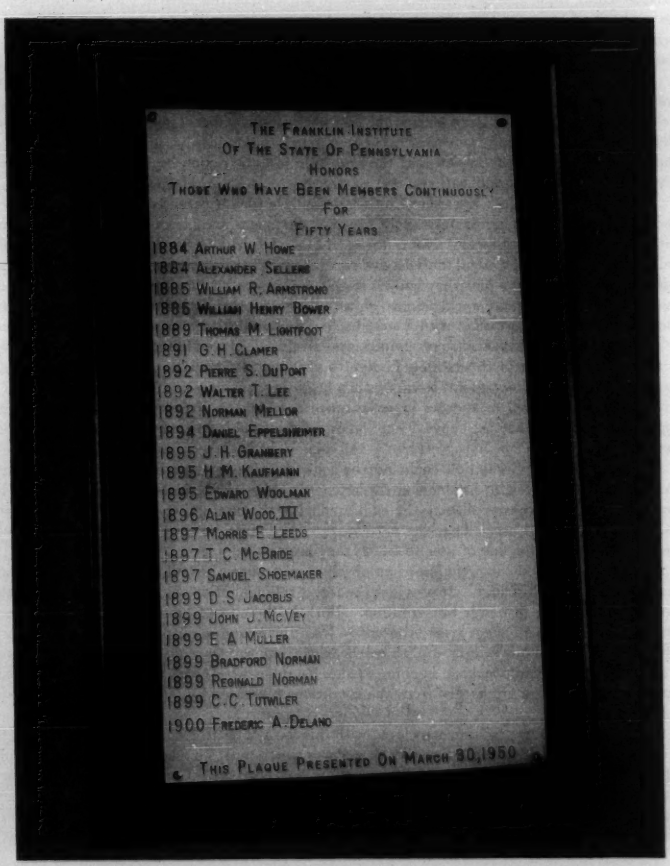
One thousand two hundred and thirty-seven years of continuous membership in The Franklin Institute are represented by twenty-two men who were honored at special ceremonies in Franklin Hall on the evening of March 30. Each of these men had belonged to the Institute continuously for fifty or more years. Eight of the members were able to be present at the dinner and receive personally the gold keys and new gold membership cards which were given to all those having a record of fifty years or more.

As president Richard T. Nalle said in his welcoming remarks to the 150 dinner guests, these members are the "post graduates," two of whom claimed sixty-six years membership apiece. These two, Arthur W. Howe of Philadelphia and Alexander Sellers of Media, were present. Remarking on the vast technological changes which have taken place in the world during these terms of membership, from horse and buggy to supersonic flight, Mr. Nalle said, "We feel it a rare privilege to count among us those who can give eye-witness accounts of matters which are of prime importance to The Franklin Institute—that is, science and its practical applications."

The full list of living members on March 30 who were thus honored includes, in addition to Mr. Howe and Mr. Sellers, William R. Armstrong, member of 65 years; William Henry Bower, member, 65 years; Thomas N. Lightfoot, 61 years; G. H. Clamer, 59 years; Pierre S. du Pont, 58 years; Norman Mellor, 58 years; Walter T. Lee, 58 years; Daniel Epplesheimer, 56 years; Edward Woolman, 55 years; J. H. Granbery, 55 years; Alan Wood, III, 54 years; Morris E. Leeds, 53 years; T. C. McBride, 54 years; D. S. Jacobus, 51 years; E. A. Muller, 51 years; Bradford Norman, 51 years; Reginald Norman, 51 years; C. C. Tutwiler, 51 years; John J. McVey, 51 years, and Frederic A. Delano, 50 years.

At the time plans were being laid for this ceremony, there were two additional members, H. M. Kaufmann with 55 years of membership and Samuel Shoemaker, member for 53 years, whose names were included on the plaque which was engraved and presented to the Institute. However, these two passed away a very few days before the occasion took place.

This plaque was so designed that additional names may be placed on it each year as more individuals reach the half-century mark of membership in The Franklin Institute.



MUSEUM

In the newly arranged Hall of Electrical Communications, attention need not be drawn to one exhibit which constantly grips the visitor's interest. This is an exhibit relating to ball bearings, placed temporarily for convenience in this room.

The history of anti-friction bearings extends into antiquity. Balls and rollers were often used to ease the path of sledges and heavy building materials as we know from pictures of the building of the pyramids. The invention of the wheel and axle brought plain bearings into existence and, from that day to this, the effort to improve on this ancient contrivance has gone on without cessation. The advent of lubrication made the plain bearing more efficient but otherwise anti-friction bearings did not make much progress until the last quarter of the nineteenth century, when the ball bearing was introduced.

Curiously enough, the ball bearing owed its advent to the bicycle. This form of bearing was developed originally by Surirary in France and Strassen in England. At the bicycle show held at the Pré Catalan in Paris, during the first week of November, 1869, bicycles incorporating these free running bearings were shown. These were found to involve such a great reduction in the effort required for propulsion that the new form of anti-friction bearings was immediately given other mechanical applications.

However, very little care was used in their design, the idea apparently being that all that was necessary to secure proper results was the use of a convenient number of reasonably round balls running between smooth races. Not much attention was given to the sizes and accuracy of the balls, the selection of the metal for balls and races, or in its treatment or finish. The resultant failures taught engineers that they had an instrument of great value if it were given adequate research and development work. So much attention was therefore devoted to its study that the ball bearing was furnished with a sound scientific foundation.

The perfection which has been attained is admirably displayed in the exhibit of SKF shown in the Museum. One of the exhibits fascinates visitors. It shows an unceasing flow of balls used in ball bearings dropped in a stream from a height onto an anvil. The ball rebounds and is directed from one anvil to another in series, until the balls finally are deposited in a central hopper. From here they are conveyed to the top of the exhibit and started in their continuous circulation once more.

This continuous circulation could not be achieved were not the balls made with precise accuracy as to size, weight, hardness and micrometric sphericity. Nothing could very well be devised which would better display the skill applied in the production of these balls which are now in such universal use. That the most minute care must be exercised in manufacture is obvious from the multitude of uses to which they are applied.

In addition to reducing friction to an absolute minimum, the ball bearing has certain advantages over other bearings. It provides the truest rolling motion of any type of bearing with a consequent saving in power consumption. Both in the cost of lubricant and maintenance labor, ball bearings can effect great economy. No adjustment repair or attention is necessary other than periodical lubrication. With ball bearings in power transmission units, where grease is used as the lubricant, leakage is eliminated. Running with consummate smoothness ball bearings eliminate the fire hazard from the conditions presented by overheated and oily plain bearings.

The extraordinary precision associated with this form of bearing enables grinding wheels to be supported as to produce the finest work. Parts which must be maintained with small but definite clearances are most successfully carried on ball bearings. Gears can be held in exact alignment and adjustment. These facts are well known to engineers and mechanics, but they become appreciable to the lay visitor who has the privilege of seeing these ball bearings performing to display their unique properties in these ingeniously contrived exhibits.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in the JOURNAL within the next few months:

MICHAELSON, HERBERT B.: Variations of Grid Contact Potential and Associated Grid Currents.

HEREFORD, FRANK L.: Concerning Meson Produced Secondary Electrons Emerging from Thin Foils.

PENNER, S. S.: Application of Near-Equilibrium Criteria During Adiabatic Flow to Representative Systems.

BEYER, ROBERT T. AND MING-YI WEI: An Extension of a Theory of Magnetic Amplifiers.

THORNTON, WILLIAM M., JR. AND EDWARD S. HAUBER: Zirconium as a Material for Fractional Weights.

WALLMAN, HENRY: An Electric Integral-Transform Computer and the Practical Solution of Integral Equations.

LAUTERBACH, KENNETH E.: Specific-Surface Determinations of Uranium Dusts by Low-Temperature Adsorption of Ethane.

KRZYWOBLOCKI, M. Z.: On the Asymptotic Expansion in Three-Dimensional Compressible Viscous Flow.

MERIAM, J. L.: Differential Analyzer Solution for the Stresses in a Rotating Bell-Shaped Shell.

LIBRARY

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A.M. until 5 P.M.; Wednesdays and Thursdays from 2 P.M. until 10 P.M.

On and after June 1, the Library hours will be 9 A.M. until 5 P.M. on Mondays, Tuesdays, Wednesdays and Fridays; 2 P.M. until 10 P.M. on Thursdays; and 9 A.M. until 12 noon on Saturdays.

RECENT ADDITIONS

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Advances in Agronomy. Vol. 1. 1949.

BARRE, JOHN HENRY AND SAMMET, L. L. Farm Structures. 1950.

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MOLLOY, EDWARD, ED. Hot Water Engineering. Edition 2. 1948.

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BONNEY, E. ARTHUR. Engineering Supersonics Aerodynamics. 1950.

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ROELKER, WILLIAM GREENE, ED. Benjamin Franklin and Catherine Ray Greene; Their Correspondence, 1755–1790. 1949.

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Haemoglobin; a Symposium. 1949.

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BURK, ROBERT E. AND GRUMMITT, OLIVER, ED. Frontiers in Colloid Chemistry. 1950.
HARNED, HERBERT SPENCER AND OWEN, BENTON BROOKS. The Physical Chemistry of Electrolytic Solutions. Edition 2. 1950.
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GIVAUDAN-DELAWANNA, INC. The Givaudan Index; Specifications of Synthetics and Isolates for Perfumery. 1949.
WALDIE, W. A. The Science of Wrinkle Finishing. 1949.

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JAEGER, JOHN CONRAD. An Introduction to the Laplace Transformation with Engineering Applications. 1949.
WALKER, ROBERT JOHN. Algebraic Curves. 1949.

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VINCENT, EDWARD T. The Theory and Design of Gas Turbines. 1950.

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EINSTEIN, ALBERT. Meaning of Relativity. Edition 3. Including the Generalized Theory of Gravitation. 1950.
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NEARING, HELEN AND NEARING, SCOTT. The Maple Sugar Book. 1950.

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GARNER, WALTER. Textile Laboratory Manual. 1949.

THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

***Abstract of* A High-Attenuation Filter for Harmonic Suppression.**[1]—A. M. PICHITINO.[2] The problem of television interference is being faced by increasingly large numbers of services using the high-frequency radio spectrum as more areas become serviced by television broadcasting stations. These services include police, airport, mobile, shortwave broadcast, diathermy, and amateur.

This paper discusses the practical design and construction of a low-pass filter which will provide 75 db. or more attenuation above 54 Mc. which will eliminate harmonic interference in almost all cases.

Design Considerations

First it is necessary to choose the characteristic impedance, Z_0, of the filter. The Z_0 of the filter to be described has been chosen to be 52 ohms for a number of reasons: The filter can be inserted directly in any 52-ohm coax transmission line; it can be inserted in a coax link to feed an antenna coupler to match any type line; it prevents harmonic currents from flowing around the filter because the coax link can be easily terminated in a correct manner at a shielded transmitter cabinet; and it is easier to construct than higher-impedance balanced types.

Next, the cut-off frequency f_c of the filter must be selected. This choice is dependent upon a number of factors. A low-pass filter theoretically will pass all frequencies below f_c unattenuated and will attenuate all frequencies above f_c by an amount determined by the type of sections used in the filter. Since ideal circuit elements cannot be realized, practical filters will show a very slight amount of attenuation (less than 0.25 db. and called "insertion loss") below f_c, and appreciable attenuation usually starts somewhat before the design f_c is reached.

The filter to be designed is to pass all frequencies below 30 Mc. with a minimum of attenuation. It might appear that an f_c slightly greater than 30 Mc. would be desirable, but another factor enters here to make the choice of f_c considerably higher. The input impedance of the filter will vary considerably within the pass-band (below f_c) unless impedance-matching end sections are used, and even then under the most favorable end-section design the impedance will remain essentially constant only up to approximately 70 per cent of f_c. Therefore, we choose an f_c of 45 Mc. (70 per cent of 45 Mc. equals 31.5 Mc.) which is slightly higher than needed but ties into the last consideration relative to f_c.

[1] Full article appears in *QST*, Vol. XXXIV, No. 1, January, 1950.
[2] Senior Research Engineer, The Franklin Institute Laboratories for Research and Development, Philadelphia, Pa.

The quantity m, which relates f_c to the frequency of maximum attenuation, f_∞, of the end sections, is given by the formula

$$m = \sqrt{1 - \left(\frac{f_c}{f_\infty}\right)^2}.$$

An m of approximately 0.6 must be used to obtain the best impedance characteristic. With an m of 0.61 (almost optimum) and an f_c of 45 Mc., the frequency of maximum attenuation, f_∞, will fall at 57 Mc., the center of TV Channel 2.

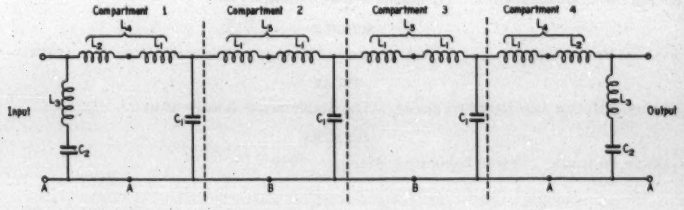

FIG. 1.—The filter circuit. Constants are calculated as follows:

$$L_1 = \frac{Z_0}{2\pi f_c} = \frac{52}{6.28(45)10^6} = 0.184\ \mu\text{h}.$$

$$L_2 = mL_1 = 0.61(0.184) = 0.112\ \mu\text{h}.$$

$$L_3 = \frac{1 - m^2}{m} L_1 = \frac{1 - (0.61)^2}{0.61} \times 0.184 = 0.189\ \mu\text{h}.$$

$$L_4 = L_1 + L_2 = 0.296\ \mu\text{h}.$$

$$L_5 = L_1 + L_3 = 0.368\ \mu\text{h}.$$

$$C_1 = \frac{1}{\pi f_c R} = \frac{1}{3.14(45)10^6(52)} = 136\ \mu\mu\text{fd}.$$

$$C_2 = \frac{mC_1}{2} = 41.5\ \mu\mu\text{fd}.$$

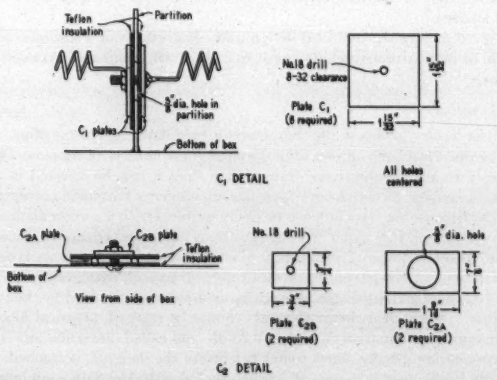

FIG. 2.—Construction of the capacitors C_1 and C_2. .Note that C_1 makes use of both sides of the partition. Capacitor dimensions are calculated as follows:

$$C = \frac{0.2245K\ (N - 1)A}{t}\ \mu\mu\text{fd}.$$

where K = dielectric constant of insulation (2.1 for Teflon),
N = Number of plates,
A = area of one side of one plate in square inches, and
t = thickness of dielectric in inches (0.015 in.).

To find area use

$$A = \frac{Ct}{0.2245K(N - 1)}$$

Engravings courtesy of QST

Three intermediate filter sections of the constant K, full T type are employed which results in a filter of four full sections. Figure 1 shows the configuration of the filter, with the series m-derived end half-sections shown between points A-A and the three constant-K full T midsections shown between points A-B, B-B, and B-A.

Construction

The filter enclosure consists of a sheet copper box 3 × 4 × 12 in. and is divided into four equal-sized compartments by means of three $\frac{1}{16}$-in. thick brass partitions. These partitions have $\frac{1}{8}$-in. diameter holes in their centers. The box corners and partitions are soldered with the box top fastened by means of metal screws.

The formulae for the filter inductors and capacitors are given under Fig. 1. Figure 2 shows the capacitor construction and formula. The capacitors are fabricated by using flat $\frac{1}{16}$-in. brass plates in conjunction with the copper box as the ground plate. The C_1 capacitors are of the feed-through type and the C_2 capacitors are straight ground type. The capacitors are assembled with 8–32 brass hardware.

The dielectric used is a comparatively new plastic, DuPont "Teflon." It has very desirable characteristics, such as low losses, high voltage breakdown, uniform thickness, can withstand moderately high temperatures compared with most plastics and is easily worked. Although the material used in the filter is only 0.015 in. in thickness, it will withstand more than 15,000 volts.

To facilitate assembly, soldering lugs should be crimped and soldered to the inductors with the lugs bent to allow clearance for tightening the feed-through bolts with a small wrench. The bolts should be carefully centered in the $\frac{1}{8}$-in. clearance holes, because here the dielectric is air and the breakdown voltage is lowest, aside from the standard coax terminal connectors. The easiest way to assure centering is to use a carefully cut $\frac{1}{8}$-in. diameter Teflon disk with an accurately centered No. 8 clearance hole. One of these disks is placed between the two pieces of dielectric in each capacitor where it will center the assembly. Inductor L_3 is carefully butt-soldered to a corner of plate C_{2A} prior to assembly. In fact, all soldering except that necessary to attach L_2 and L_4 to the standard coax terminal fittings mounted on each end of the enclosure should be done prior to mounting the dielectric, to avoid possible damage due to excessive heat.

Characteristics

The filter provides greater than 75 db. attenuation above 54 Mc. with an insertion loss of less than 0.25 db. The power handling capability is greater than 1250 watts, 100 per cent amplitude-modulated and has a flat characteristic impedance curve within the pass-band.

Radio services which have successfully employed this filter include police, mobile, airport, diathermy and amateur.

BOOK REVIEWS

PHENOMENA, ATOMS AND MOLECULES, by Irving Langmuir. 436 pages, illustrations. New York, Philosophical Library, 1950. Price, $10.00.

There are many ways of writing a book but the least desirable of them is to collect papers which have appeared in journals of the past and publish them in book form. Not that this reviewer seeks to define the proper methods of writing books but it seems that what is textually an excellent book contains many opinions which are completely out of date.

It appears the author did not trouble to read the manuscript after it was set up. Otherwise one could not find a sentence on page 17 which reads, "This subject has been very ably discussed by Walter J. Murphy in an editorial in the September number of *Chemical and Engineering News*." September of what year? Certainly if the chapter had been published in 1945 as a note on the *Joint Hearings of Science Bills* it may have been all right to say September. Then the readers would know September 1945 was the one in question. But in a book which may be picked up 20 or 50 years later, merely saying September is not enough. The chapter, to be an integral part of the book, must have the year included.

Concerning the Russians, Dr. Langmuir says on page 31, "During negotiations one is kept guessing as to their intentions until the time for decision has arrived and a contract is signed. Then they *live up to their commitments scrupulously.*" Does Dr. Langmuir read any daily papers? Certainly the evils of the above method of writing a book are spotlighted by items like these.

Getting away from the justified criticism of the methodology and into the meat of the book we find some excellent and fully illuminating writing. In reading of Dr. Langmuir's early work on the incandescent lamp we see how the true research spirit works. Dr. Langmuir discloses the side effects of pure research and their tremendous importance to the technology of today. For instance, in the research on atomic hydrogen the way was indicated for the invention of the gas-filled lamp. One feels that it is regrettable that only in the very largest research institutions can the scientist be permitted to indulge in researches which have no immediate bearing on the product some company sells.

Throughout the book are marks of the character of the author. By stating the various steps involved in a problem he discloses the operations of his mind in approaching the solution. Each step is carefully planned with due regard for what went on before and in many cases the results are foreseen.

The reviewer's first introduction to Dr. Langmuir's experimental approach took place in 1938 when he published an article in *Science* on the "Speed of the Deer Fly." In this brief paper there is contained the complete analytical and experimental approach to the problem of speeds. Dr. Langmuir completely demolished the notion of excessive speeds for these flies. He showed that the speed is probably on the order of 25 miles per hour instead of the 600–800 miles per hour quoted in numerous publications.

In *Phenomena, Atoms and Molecules*, Dr. Langmuir has told the story of his researches in many fields. It makes intensely interesting reading and may well act as a guide for the coming generation of scientists. The price of the book, $10.00, puts it beyond the reach of many people who would own a copy. The reviewer cannot reconcile this price with a 400 page book containing very few cuts and no difficult typesetting.

I. M. LEVITT

THE PERSONALITY OF WILLIAM HARVEY, by Geoffrey Keynes. 48 pages, plates, 13 × 20 cm. Cambridge, University Press, 1949. Price, $1.00.

It is a curious fact that there is a paucity of information upon the character, personality, and intimate life of scientists. Even a giant like Newton is almost a total stranger to the stu-

dents of his work. No one seems to take the trouble to observe the man, so busy are the scientists in observing the results of the man's work. This absence of a personality becomes more noticeable among the earlier scientific workers. It was, therefore, a happy choice which guided Geoffrey Keynes, the eminent British surgeon, when he was invited to give the Linacre Lecture at Cambridge.

In selecting as his subject "The Personality of William Harvey" Dr. Keynes has done a service for scientific literature in presenting a better rounded picture of the renowned discoverer of the circulation of the blood. For Harvey is known by his accomplishment to most science students, but very few could have furnished an outline sketch of the man himself. Dr. Keynes has not confined himself to the scanty hints dropped by contemporary acquaintances, he has used his professional knowledge to make a thorough examination of the known portraits. An interesting outcome of Dr. Keynes' essay is to elucidate once and for all the problems of Harvey's portraiture and, by his own research, to have found an additional portrait of the great anatomist.

T. C.

SOME EARLY TOOLS OF AMERICAN SCIENCE, by I. Bernard Cohen. 201 pages, plates, 16 × 25 cm. Cambridge, Harvard University Press, 1950. Price, $4.75.

On February 12, 1949, there was placed on display in the Edward Mallinckrodt Chemical Laboratory of Harvard University a selection of Harvard's holdings of old scientific instruments and specimens of the period 1764 to 1825. This book was prepared as a commemorative volume for the exhibition, but Dr. Cohen found so much matertial relating to the background of the instruments and allied matters that the work has been considerably expanded.

In his introductory chapter the author points out some of the ways in which the study of the history of science at such an institution as Harvard might be approached. He further emphasizes that the present work is not such a full-scale history but rather a sketch, "only enough information being given so that the reader may visualize the role of the instruments described in the system of education then in operation." Within these limits is included material on the kind of teaching offered, the contents of the lectures, and the growth of teaching in the various departments of the sciences. For each department he has limited the discussion to the founding period, namely the 18th century for astronomy and natural philosophy; for chemistry, natural history and mineralogy, the study covers the closing years of the 18th and the first part of the 19th centuries.

In his discussion of the instruments for astronomy and natural philosophy, Dr. Cohen finds a natural division in the disastrous fire of 1764 which destroyed Harvard Hall with the Library and the Philosophical Apparatus. Although only one piece of apparatus, a telescope, is known to have escaped the fire, sufficient records have survived to enable Dr. Cohen to present a full outline of the major pieces in the collection. The exact appearance of much of this equipment is also known, for in an inventory of 1738 reference is made to the plates of a printed booklet, the pertinent portions of which have been reproduced herewith. That Harvard was indebted to its friends for most of its equipment is amply brought out, and due credit is given to Thomas Hollis, who provided much apparatus in connection with the establishment of the Hollis Professorship of Mathematics and Natural Philosophy in 1727.

Although the fire was a serious blow, the friends of the college rallied around, and by 1779 when another inventory was prepared, the collection was again as fine if not better. In this replacement, Benjamin Franklin proved a good friend to the New England school, offering both advice and assistance. It was during this second period, in 1787, that the Pope orrerry, one of the best-known pieces of Harvard apparatus, was constructed for the college.

Separate chapters have been devoted to chemistry and to the biological sciences, whose teaching developed later. By 1821 there had been gathered quite an array of chemical apparatus and equipment for purposes of experimentation and demonstration. The biological sciences on the other hand, required little apparatus, but instead provided the opportunity for acquiring numerous specimens. Dr. Cohen has investigated the problem of microscopes in some detail, because of the confusion that has arisen over the use of the term "double microscope." He finds that there seems little reason to doubt that the Harvard microscope presented by the second

Thomas Hollis in 1731 was the first compound microscope acquired by a New England College.

However, it is not alone in the textual matter, with accounts of the acquisition of apparatus and with vignettes of the men who were responsible for its use and care, that the value of the book lies. The excellent photographs of the apparatus in the exhibition, with the descriptive notes prepared primarily by David P. Wheatland, Curator of the Collection of Historical Scientific Instruments at Harvard, add greatly to the importance of the book. Similarly, the inventories of apparatus which Dr. Cohen reprints in full are essential for an understanding of the variety of equipment that was available in one American institution during Colonial and Federal days.

In thus presenting much primary source material previously unpublished, Dr. Cohen has rendered a great service to the student of early American science. Likewise, the student of American culture will need to refer to this book for Dr. Cohen has proven that the teaching of science in Colonial and Federal America was not the neglected subject it was once assumed to have been.

G. E. PETTENGILL

FARADAY'S DISCOVERY OF ELECTROMAGNETIC INDUCTION, by Thomas Martin. 160 pages illustrations, 13 × 19 cm. London, Edward Arnold & Co., 1949. Price, $2.00.

It is a defect of our educational method that the young scientist is permitted to feel that there is nothing remarkable in the enunciation of the laws of motion, of electromagnetism, of the vacuum—ideas which are presented to him in such simple form that the marvel of the discovery escapes him. He reads in his textbooks of the experiments of a Galileo, a Faraday, and a Guericke, and feels that they are so obvious that he could have made them himself, knowing nothing of the opinions prevailing nor of the apparatus available at the time the master made his discovery.

It is instructive, therefore, to have a day to day account of Michael Faraday's endeavors during the fall of 1831 to discover the secret of electromagnetism. The author of this little book edited Faraday's *Diary* which added much information to what was known of the great experimental physicist's electrical researches. He has now compiled an historical account of the electromagnetic experiments which illustrates what Faraday did, what apparatus he worked with, and how he made the series of observations which constitute the discovery of electrical induction.

Mr. Martin reveals the difficulties and doubts of Faraday, who had no means of accurate measurement nor any idea of the effects which were to be measured. Drawing upon Faraday's notes and sketches, he shows that this fundamental discovery was not the result of any chance observation but was the outcome of years of preparation. The resultant work adds to the general knowledge of facts and particulars which the lapse of time has made significant and interesting. No student of electricity should neglect to read this little book. It should serve as a guide and inspiration, showing what can be achieved by the experimental method without the aid of mathematics.

T. C.

PHYSIOLOGY OF THE EYE—VOL. I.—OPTICS, by Arthur Linksz. 334 pages, illustrations, 17 × 26 cm. New York, Grune & Stratton, 1950. Price, $7.50.

This unorthodox textbook is the first of a series of three planned by the author for students of ophthalmology. It is unorthodox because Dr. Linksz has achieved a degree of informality found only in classroom lectures; the book is essentially a transcript of such lectures given over the past years. The author possesses the happy faculty of presenting accurate details with a clarity seldom found, especially in engineering or physics textbooks, yet with a minimum of mathematics. Engineers, engineering and physics students can well profit by reading a book of the physics of light, geometrical optics, and the eye as an image-forming mechanism as seen by a physician.

The first five chapters are devoted to the nature and physics of light, presenting a review of: the continued conflict between the corpuscular and wave theory; reflection and refraction phenomena; light rays, heat, and radiation; and the elements of photometry.

The second section is devoted to geometric optics, treating of mirrors, lenses, prisms, and aberrations. In these chapters, the author deals with the fundamental problems which eventually allow the ophthalmologist to have an intelligent approach to the practice of clinical refraction. Geometric optics is developed as a useful tool for understanding the process of vision. A clear discussion of the mode of operation of the plane mirror emphasizes that this is not an image-forming mechanism but rather a means for changing the direction of light rays as contrasted to curved mirrors which form an image, a fact many times entirely neglected in introductory physics texts. Refraction problems are studied through single interface spherical lenses, thick lenses, thin lenses, cylindric and toric lenses, prisms and prismatic effect of lenses. Quite naturally these topics lead to those pertaining to aberrations, their causes, effects, and means available for correction. These chapters should be of especial interest to designers of optical systems. In conformance with general opthalmological practice, the unit of power used is the diopter and all computations are so carried out.

The eye as an optical instrument and as a biologic entity is the subject of the last section. A review of the history of measurements of the physical optical characteristics of the eye shows how such things as the focal points of the eye and the equivalent planes are determined. The elements of refraction using correction lenses are illustrated in sample problems for the cases of axial myopia and axial hyperopia.

This reviewer found the informal style most exhilirating, almost as if the author were actually present discussing the subject matter. The book can well be used as an auxiliary reference work for those not in the field of ophthalmology.

S. CHARP

BOOK NOTES

HYDROELECTRIC HANDBOOK, by William P. Creager and Joel D. Justin. Second edition, 1151 pages, illustrations and plates, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1950. Price, $12.50.

Now first revised since 1927, this edition of the "Hydroelectric Handbook" has been augmented by the addition of some two hundred fifty pages. There has been some rearrangement of chapters with new ones added and the division of the work into four main sections. The first is devoted to natural factors as rainfall, evaporation, runoff, river gaging, flood wells, and to other preliminary topics as types of hydroelectric plants, pondage and storage, costs, and other economic factors. Part two treats of different types of dams in detail while part three considers conduits and powerhouses, with separate chapters being devoted to such topics as conduits, canals, tunnels, water hammer, power plant substructure and superstructure. The final section treats of equipment and operation—hydraulic turbines, generators, wiring, transmission lines. The principal authors have had the assistance of eighteen collaborators who have contributed chapters or parts thereof. A comprehensive book with much illustrative material and suggestive bibliographies.

THE RIGID-FRAME BRIDGE, by Arthur G. Hayden and Maurice Barron. Third edition, 240 pages, illustrations, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1950. Price, $5.00.

This new edition features an entirely new and vastly simplified method of analysis for skewed frame bridges which was worked out by Mr. Barron. The many advantages of this new method should promote the use of the rigid-frame bridge when a skew bridge is needed. Other new material and illustrations have been added, while much obsolete material has been dropped to bring the volume up-to-date.

FARM STRUCTURES, by H. J. Barre and L. L. Sammet. 650 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1950. Price, $7.00.

Designed as a textbook for students in agricultural engineering, "Farm Structures" is so written that it may be used as a two semester course. The first part includes structural mater-

ials, functional requirements, and economic aspects, topics which should prove useful to agricultural engineers in all fields of specialization. The second part deals with the design of structural members and frames, intended for students specializing in farm structures. An effort has been made to maintain a suitable balance between theory and practice. This is the inaugural volume of the new Ferguson Foundation Agricultural Engineering Series.

PLANT PATHOLOGY, by Sir Edwin J. Butler and S. G. Jones. 979 pages, illustrations, diagrams, 17 × 25 cm. London, Macmillan Co., Ltd., 1949. Price, $10.00.

Conceived originally as a revision of the late Sir Edwin Butler's book "Fungi and Disease in Plants" published in 1918, the present work is essentially entirely new. Its plan embraces two parts, "General Diseases" and "Selected Diseases" of which the first is largely the work of Sir Edwin, while the second is primarily that of Dr. Jones. The subjects covered in the first part include the nature of disease organisms, the parasitic fungi, the influence of environmental and nutritional conditions on plant diseases, the principles of the control of plant disease, virus diseases and deficiency diseases.

The second part is arranged by types of plants and under each considers the most important diseases common to each host. From the agricultural viewpoint, this is undoubtedly more valuable as it emphasizes the plant rather than the disease grouping. In contrast to the earlier volumes which emphasized tropical diseases, the present work considers plant diseases of importance in Great Britain.

Over four hundred illustrations and extensive bibliographies with each section add much to the book's reference value. A comprehensive work which should well meet the needs of students of mycology, plant pathology, agriculture, horticulture, and forestry for whom it is designed.

ELÉMENTS DE CALCUL TENSORIEL, by A. Lichnerowicz. 216 pages, 11 × 16 cm. Paris, Librairie Armand Colin, 1950. Price, 180 fr. (paper).

This new addition to the "Collection Armand Colin" treats of the elements of tensor calculus, and is presented as a necessary introduction to the great theories of physics and modern techniques. The first part comprises an elementary but rigorous presentation of the basic theory both of tensor algebra and tensor analysis. The second part discusses some of the various applications in classical dynamics, electrodynamics and the theory of relativity.

HANDBOOK OF BASIC MOTION-PICTURE TECHNIQUES, by Emil E. Brodbeck. 311 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., 1950. Price, $5.95.

An informed presentation of the techniques of making motion pictures, this book reflects extensive research conducted by the United States Signal Corps and Celluloid College to discover and overcome the "stumbling blocks" in the path of the movie maker. These blocks, ten in number, provide the basis of the chapters, which have been arranged in the order in which the difficulties should be eliminated to promote most effectively the advancement of the beginner. The topics are panning, using the tripod, shot breakdown, screen direction, matching action, newsreel techniques, build-up, composition, indoor lighting, and applied techniques. A preliminary chapter considers general matters relating to both the mechanics and techniques of movie making.

PSA JOURNAL 1950 ANNUAL. Illustrations, plates, 22 × 28 cm. Philadelphia, Photographic Society of America, 1949. Price, $1.00.

This special issue of the *PSA Journal* offers articles on various phases of photography—color, nature, pictorial, motion picture, and technical. The varied contents may be indicated by some titles: "Outdoor-fashion photography," "Moth photography," "Some factors effecting sepia tone." "Singing pictures" by H. Lou Gibson suggests the interesting possibility of matching pictures and verse.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

The Preparation of Some 6-Substituted Nicotinic Acids.— FRANCIS E. REINHART. The preparation and bacteriostatic activity of several *ortho* substituted benzoic acids formed the subject of a recent NOTE (1) from this laboratory. Although closely related to 5-nitro-2-pyridyl phenyl sulfone, these acids showed no bacteriostatic activity toward *Staphylococcus aureus* comparable to that previously observed for the parent sulfone. As an extension of this study, there have been prepared and tested several 6-substituted nicotinic acids which are isomerically related to these benzoic acids. Table I lists these new acids as well

TABLE I.—*Properties and Analyses of Compounds*

No.		M.p., °C. (uncor.)	Yield, %	Formula	Analyses,* % Sulfur Calcd.	Found	Minimal[a] Inhibitory Conc. mg./100 ml.
	Nicotinonitrile						
I	6-(*p*-Nitrophenylmercapto)-	133–5	73	$C_{12}H_7O_2N_3S$	12.46	12.72	
	Nicotinic Acid						
II	6-(*p*-Nitrophenylmercapto)-	210	81	$C_{12}H_8O_4N_2S$	11.61	11.72	5
III	6-(*p*-Aminophenylmercapto)-	196–8	69	$C_{12}H_{10}O_2N_2S$	13.02	13.19	50
IV	6-(*p*-Nitrophenylsulfonyl)-	226–8 dec.	76	$C_{12}H_8O_6N_2S$	10.40	10.48	25
V	6-(*p*-Aminophenylsulfonyl)-	232-3 dec.	80	$C_{12}H_{10}O_4N_2S$	11.52	11.54	[b]
VI	6-Amylmercapto-	94-5	70	$C_{11}H_{15}O_2NS$	6.22[c]	6.01[c]	80

[a] See Reference (1).
[b] Inactive.
[c] Nitrogen.
* The microanalyses were performed by Miss Lorna A. Wells and Mrs. Jane K. Wunz of our laboratories.

as the intermediate nitrile used in their preparation and also an additional related compound, 6-amylmercaptonicotinic acid.

A convenient starting point for the preparation of the acids was found in the fusion of 6-chloronicotinonitrile and *p*-nitrobenzenethiol to give the nitrile (I) which yielded 6-(*p*-nitrophenylmercapto)-nicotinic acid (II) on hydrolysis. Hydrogen peroxide converted the latter to the sulfone (IV) while reduction with ferrous hydroxide afforded 6-(*p*-aminophenylmercapto)-nicotinic acid (III). A similar reduction applied to sulfone (IV) gave the nicotinic acid (V). For the preparation of (VI), amyl mercaptan and 6-chloronicotinonitrile were heated in ethanolic potassium hydroxide and the mixture hydrolyzed with aqueous alkali without isolation of the intermediate nitrile.

In Table I are recorded the bacteriostatic activities of these acids for *S. aureus* as determined by the procedure previously used (1) for the *ortho* substituted benzoic acids. The most active of the group was 6-

(*p*-nitrophenylmercapto)-nicotinic acid which completely inhibited growth at a level of 5 mg. per cent. No activity was observed for 6-(*p*-aminophenylsulfonyl)-nicotinic acid at concentrations as high as 150 mg. per cent.

6-(p-Nitrophenylmercapto)-nicotinonitrile.—Two known compounds, *p*-nitrobenzenethiol and 6-chloronicotinonitrile, were required for this preparation. The former was obtained in 45 per cent yield from *p,p'*-dinitrodiphenyl disulfide by the procedure described for the *ortho* isomer (2). Attempts to prepare the nitrile from 5-amino-2-chloropyridine by the Sandmeyer reaction as described by Räth and Schiffmann (3) gave very poor results. Yields of about 60 per cent, however, were attained by use of the following modification:

> A solution of 5-amino-2-chloropyridine (12.8 g.) in water (100 ml.) and concentrated hydrochloric acid (60 ml.) was diazotized at 0–5° C. with sodium nitrite (7 g.) in water (30 ml.). This cold solution was then stirred during ¾ hr. while magnesium oxide (9 g.) was added in small portions. The temperature was maintained at 0–5° C. during the addition.
>
> A cuprous cyanide solution was also prepared by suspending cuprous chloride (made from 31.3 g. cupric sulfate (4)) in water (50 ml.) and adding a solution of sodium cyanide (16.3 g.) in water (50 ml.).
>
> The cyanide solution was put in a 2 l. beaker, cooled to 0–2° C., and mechanically stirred during ¾ hr. while the cold diazonium solution was gradually added. Small amounts of ether were used to minimize frothing. The mixture was then stirred for an additional half hour while it was allowed to warm to 25° C. After standing several hours magnesium oxide (2 g.) was added and the mixture steam-distilled to yield 7.5–8.0 g. of the chloronitrile, m.p. 113–115° C.

A mixture of *p*-nitrobenzenethiol (9.4 g.) and 6-chloronicotinonitrile (8.3 g.) was pulverized in a mortar and then heated in a flask at 90° C. During the first 20 min. fusion to a red liquid occurred and hydrogen chloride was evolved. Finally a yellow solid was formed. After heating had been continued for an additional 1½ hr., the solid was removed and pulverized. Soluble impurities were removed by extraction with a cold mixture of 95 per cent ethanol (80 ml.), water (5 ml.), and 2 *N* sodium hydroxide (10 ml.) followed by washing on the filter with cold 95 per cent ethanol. The extract, which was discarded, was colored deeply red. The bright yellow product, after recrystallization from 450 ml. 95 per cent ethanol, weighed 11.3 g. It was soluble in benzene, slightly soluble in cold ethanol and practically insoluble in water.

6-(p-Nitrophenylmercapto)-nicotinic Acid.—A suspension of pulverized 6-(*p*-nitrophenylmercapto)-nicotinonitrile (8 g.) in 2 *N* sodium hydroxide (160 ml.) was heated to 100° C. for 2 hr. with stirring, during which time

ammonia was evolved. The mixture, containing a small amount of solid material, was diluted with water (140 ml.), adjusted to pH 7–8 with dilute hydrochloric acid, and centrifuged to remove insoluble impurities. The supernatant liquid was then treated with 2 *N* hydrochloric acid (20–25 ml.) to precipitate the yellow product which was separated by filtration and washed with water. Recrystallization from 400 ml. dilute ethanol (50 vol. per cent) gave 7.0 g. of the purified acid as yellow prisms. It was soluble in ethanol and in hot glacial acetic acid but practically insoluble in water. When dissolved in 3 *N* sodium hydroxide, it was soon converted to relatively insoluble crystals which appeared to be those of the sodium salt.

6-(p-Aminophenylmercapto)-nicotinic Acid.—A solution of ferrous sulfate heptahydrate (26 g.) in water (120 ml.) was treated with 25 ml. concentrated ammonium hydroxide. To this mixture was added gradually with stirring a solution of 6-(*p*-nitrophenylmercapto)-nicotinic acid (4 g.) in water (60 ml.) containing 1.5 ml. concentrated ammonium hydroxide. After stirring for 1 hr. the iron precipitate was removed by centrifugation. The supernatant liquid was warmed with Darco, filtered, and added to one obtained by extraction of the iron residue with 100 ml. water to which had been added 2 ml. ammonium hydroxide. The solution was then cooled and carefully treated with 6 *N* hydrochloric acid (to pH 4) to precipitate the product.[1] Recrystallization from 650 ml. water yielded fine colorless needles (2.5 g.) which were soluble in ethanol and very insoluble in cold water.

6-(p-Nitrophenylsulfonyl)-nicotinic Acid.—To a suspension of 6-(*p*-nitrophenylmercapto)-nicotinic acid (4 g.) in glacial acetic acid (50 ml.) was added 6.4 ml. hydrogen peroxide (30 per cent). The solid dissolved on shaking the mixture at 90° C. for 10 min. Heating was continued at this temperature for 1 hr. after which time precipitated crystals of the sulfone were observed. After cooling and adding water (50 ml.) the product was collected on a filter and washed with water. Recrystallization from 175 ml. aqueous dioxane (35 vol. per cent) gave 3.4 g. cream-colored plates which were soluble in dioxane but only very slightly soluble in ethanol and in water. The compound dissolved in *N*/2 sodium hydroxide solution but when added to 2 *N* solution it was converted to insoluble needles which appeared to be those of the sodium salt.

6-(p-Aminophenylsulfonyl)-nicotinic Acid.—A solution of ferrous sulfate heptahydrate (37 g.) in water (400 ml.) was treated with 140 ml. 2 *N* sodium hydroxide; the mixture was centrifuged and the iron precipitate suspended in 75 ml. water. To this was added with stirring a solution of the sodium salt of 6-(*p*-nitrophenylsulfonyl)-nicotinic acid prepared from 6.16 g. of the free acid, 200 ml. water, and 11 ml. 2 *N*

[1] When the precipitation was effected at pH 2.5, the product appeared to be the sulfate, m.p. 253°C.

sodium hydroxide. Stirring was continued for 1 hr. after which the mixture was centrifuged and the supernatant liquid acidified (to near pH 2.5) with 2 *N* hydrochloric acid to precipitate the product. A small additional amount of the latter was obtained by extraction of the iron residue with 100 ml. water containing several ml. of 2 *N* sodium hydroxide and subsequent acidification of this extract. The crude acid was recrystallized from dilute ethanol (35 vol. per cent) to give 4.4 g. of yellow prisms which were soluble in ethanol and very slightly soluble in water.

6-Amylmercaptonicotinic Acid.—To a solution composed of *n*-amyl mercaptan (3.6 ml.), ethanol (60 ml.), and potassium hydroxide (1.63 g.) contained in a flask provided with a reflux condenser was added 6-chloronicotinonitrile (4 g.). After the mixture had been heated on the water bath for 1½ hr., 120 ml. of 2 *N* sodium hydroxide were added and heating was continued for 2 hr. The product was then precipitated by acidification with 2 *N* hydrochloric acid. It was removed by filtration and recrystallized from 80 ml. dilute ethanol (50 vol. per cent) to yield 4.6 g. light yellow plates which were found to be soluble in ethanol and in benzene but very slightly soluble in water.

(1) F. E. REINHART, JOUR. FRANKLIN INST., **249**, 248 (1950).
(2) H. LECHER AND K. SIMON, *Ber.*, **55B**, 2423 (1922).
(3) C. RÄTH AND F. SCHIFFMANN, *Ann.*, **487**, 127 (1931).
(4) "Organic Syntheses" Coll. Vol. I, p. 170, New York, John Wiley and Sons, Inc. (1941).

CURRENT TOPICS

Stand Up and Be Counted.—This is the year in which the Seventeenth Decennial Census of the United States is to be taken by 140,000 enumerators—fact-finders for the nation—who must canvas 45 million American dwelling units and over 6 million farms containing 150 million Americans. They have the task of collecting the largest single body of data available for general use, the largest single statistical survey ever made.

Two hundred questions—though not everyone will be asked all of them—make up the questionnaires for this year's census, covering population, housing, and agriculture; two hundred questions to be asked from the Mississippi Delta country to above the Arctic Circle; two hundred questions to be asked from the Maine lobster pots to the smudge pots in the California orchards.

The Census Law requires completion of all reports by December 31, 1952! And by December first of this year the official population figures for each state must be compiled and given to the President so he in turn can pass this information on to the 82nd Congress!

Even if this were not the age of supersonic missiles and jet propulsion, speed in assembling and analyzing all data obtained in the 1950 Census would be of the greatest importance. Because, as any businessman knows, there is no value in facts that are outdated, and there is no use for facts that are available only in one huge undigestable mass—unsorted and unanalyzed.

With today's modern machine methods the job can be done, and Bureau of the Census of the United States Department of Commerce knows how to do it. They know, as does the businessman with vision, that this is not only the Atom Age, it is also the Age of the Punched Card.

The millions of facts collected in the Seventeenth Decennial Census will be recorded on 270 million punched cards—one for every person, one for every dwelling unit, and eight or more for every farm.

If, for example, you are presented by the enumerator with one of the questions asked for every fifth dwelling unit, the fact that you have or do not have a television set will appear as a small rectangular hole punched in the proper column of an IBM Card.

Let us follow that punched hole for one moment.

The card in which that hole is punched will contain all the other information obtained about the dwelling unit in which you live. The cards will then be automatically sorted, and those cards with a hole in the place coded for television set owners will be selected from those cards with no punched holes in that spot. Then statistical and accounting machines will print the results into desired tables.

The scope of the sorting operation alone can be visualized best when we realize that the task of transferring the basic facts from Census questionnaires to the cards by means of key punch machines will take about a year, and it is said that approximately two million cards will be punched every day at operation peak.

All this seems like an impossible task, but American engineering skill and

the vision of American business must also be considered. The International Business Machines Corporation, which under the leadership of Board Chairman, Thomas J. Watson, has done so much to increase the productivity of business and industry, has added the speed of electronics to the accounting machines which have done such yeoman service throughout the world.

The Electronic Statistical Machine, used for the first time in the Seventeenth Decennial Census, is specially designed by IBM for the Census task.

Prior to the development of this machine, it is estimated that working by hand it would take 500 persons all of their working lives to accomplish what the IBM Electronic Statistical Machines will do during the 1950 Census period.

In one operation this machine combines the simultaneous functions of classifying, counting, accumulating, and editing. It then prints the statistical data resulting from groupings of information and automatically balances the totals to insure their accuracy.

One of the most fascinating features of the new machine is its editing function which automatically detects and rejects punched cards containing improbable data. For example, a card might indicate through error that an eight-year-old boy is a war veteran. The electronic machine's editing feature will automatically reject this card. This automatic editing feature eliminates the need for manual editing involving visual examination of millions of questionnaires to make certain that entries were properly made in the right places and that the information is both reasonable and consistent. In other words, the money that is to be spent on the 1950 Census will be spent in obtaining *facts* and not in the time-consuming and costly task of verifying them.

But still, the correct facts have to be ready in time, and the IBM Electronic Statistical Machine fills the bill in this direction too. It has speed as well as versatility. It can count up to 10,000 units in each of sixty classifications while at the same time sorting the cards, which contain the data, into predetermined groups at the rate of 450 cards a minute. For the facts to be readily digestible—to be of use to American business and our government—the totals for major classifications can be broken down into smaller classifications. For example, the total number of farms in any given State can be counted at the same time they are broken down into as many as sixty size and ownership ranges.

The Electronic Statistical Machine has two separate printing mechanisms, which operate in a manner similar to a typewriter carriage. These allow the machine to print on a single line not only the totals for each of the sixty groups, but also the grand totals. And—as a further check for accuracy—the printed totals of each of the sixty groups are balanced automatically against the grand totals!

At the same time these other operations are being performed, all of the information can be relayed automatically to another machine connected by cable to the statistical machine and punched into cards for use later on in the preparation of still other statistical reports.

The working parts of the IBM Electronic Statistical Machine are: 144 tubes, 283 relays, 240 unit counter positions, 75 circuit breakers, 30 emitters, 10 high speed accumulating positions, 270 possible printing positions, 13,500 taper plug connections, and 50 miles of wiring.

The statistical machine and IBM's other electronic business machines are the result of and embody developments from the construction of large IBM

calculators for pure and applied science, the latest of which is the huge IBM Selective Sequence Electronic Calculator so recently in the news when it was used in the preparation of the mathematical equivalent of a slow-motion picture of the splitting of the atom, completing more than 12 million calculating operations to obtain the step-by-step description of the process by which the uranium nucleus divides into smaller parts with an immense energy release.

The application of electronics to calculating machines makes available more information without the heavy amount of painstaking calculations heretofore required. In fact, the application of electronics to business machines has progressed to such an extent that such machines are coming off the assembly line at the rate of forty a month at the Poughkeepsie, New York, plant of International Business Machines Corporation for almost a year.

The application of electronics to the 1950 Census will insure its being done in the time allotted—and done correctly. And just as periodic inventories and current operating statements are the practice in any successful business, so our country's increasingly complex activities and inter-relationships must be inventoried and evaluated. Measuring the economic and social changes of the Nation is the present-day job of the Census Bureau. What started out in 1790 as a relatively simple population count has grown into what really is the world's biggest continuous statistical operation. And just as American ingenuity built our country, so has American ingenuity given our country tools to measure that growth—tools like the IBM Electronic Statistical Machine—the "work-horse" of the 1950 Census.

"Starved" Radio Tubes.—A new circuit design, which results in "starved" operation of radio tubes and makes possible a new simplified three-tube radio receiver giving five-tube performance, may make possible the first $5.00 radio set of the future, according to W. K. Volkers, consulting engineer of Schenectady, speaking recently before the annual convention of The Institute of Radio Engineers.

In his paper on "Ultra-High Gain Direct-Coupled Amplifier Circuits," Mr. Volkers explained that by incorporating the principle of "starvation" in a direct-coupled amplifier, there is a drastic increase of over-all gain permitting reduction in the number of amplifier tubes and reduction of manufacturing costs such as in a three-tube radio having only four resistors and four condensors.

Electronic Brains "Shrinking."—New, simple electronic tubes, capable of such functions as addition, subtraction, multiplication and selection, and which replace functions of complicated circuits are novel developments in the new tendency toward greatly decreasing the size and complexity of computers popularly known as "Electronic Brains," according to Josef Katz of the University of Toronto. He presented a paper on "A New Class of Switching Tubes for Digital Applications," at the annual convention of The Institute of Radio Engineers.

Mr. Katz explained that the new tubes contain one electrode for each input and one for each output channel, designed so that particular combinations of input voltages result in current flow to the corresponding combinations of output electrodes. Such tubes are already applied in nuclear discriminator counters.

According to Mr. Katz, the decrease in size and complexity of electronic computers will lead to their wider application in science and industry.

Large savings in the cost of reproducing engineering drawings are possible through use of a recently developed commercial process known as Xerography, which the Air Materiel Command has found adaptable to reproduction from microfilm of the thousands of detailed drawings required each year. The method employs a charge of static electricity on a sensitive metal plate. Original reproduction will be less expensive, and storage space will be saved as well.

Buttons, Buckles and Fasteners Can Now Be Dry-Cleaned and Laundered. —The textile and fabrics industries have, for many years, been bothered by the spoilage of buttons, buckles, fasteners and ornaments due to dry cleaning, washing and ironing.

Plastics, painted or lacquered items would either soften, fade, run or change colors during dry cleaning, laundering or ironing. Many manufacturers, to avoid this difficulty have covered the fasteners etc. with cloth to match the rest of the garment. This too is not entirely satisfactory due to the poor wearing life of such cloth-covered items.

Dry cleaners have therefore made it a practice either to remove these items before cleaning, or to shift the responsibility to the owner of the garment.

Now practically all of the above items can be made in the colors of the rainbow, which are resistant to both the dry-cleaning and laundering tests.

When made of certain selected alloys of aluminum and electrolytically processed by the Mirrodip Electrodizing process, buttons, buckles, fasteners and ornaments can be made to match practically any color except pure white. Dull matte, diffuse or reflective specular surface effects are available in many colors including blue, green, red, in solids and pastels, and brown, wine and black.

The colors are not plated on the aluminum as copper or nickel or chromium is plated on a metal. Instead the colors are absorbed and fixed into the electrolytically treated aluminum surfaces so that they really become a part of the metal. Gold, silver, copper, nickel, chromium, rhodium or other metal effects can be produced that have much better wear and corrosion resistance than the plated metals themselves, lacquered or unlacquered. Peeling, chipping or lifting cannot occur. The finishes are resistant to handling, atmosphere, foodstains, alcohol, perfume, boiling water, and many chemicals including acids and alkalies. Even the high heat of a lighted cigarette end will not affect the finishes. No lacquers are required.

The costs of finishing are quite low, and, coupled with the low first-cost of the aluminum, excellent economics results.

For further information, address Technical Processes Division of Colonial Alloys Co., Philadelphia 29, Pa.

Fire extinguishers twice as effective as ordinary agents have been discovered in tests of a series of compounds in the bromofluorocarbon group, conducted by the Engineer Research and Development Laboratories at Fort Belvoir, Va. These compounds put out gasoline and electric fires easily, while identical quantities of carbon dioxide and carbon tetrachloride were not effective. Toxicity tests of the compounds are scheduled.